SOLAR WATER HEATING SERVICE AND REPAIR MANUAL

presented by the RENEWABLE ENERGY TRAINING INSTITUTE

sponsored by SANDIA NATIONAL LABORATORIES

prepared by AAA SOLAR SUPPLY INC./SEMCO

A manual for solar technicians to assist in the installation, alteration, repair and maintenance of large and small solar water heating systems.

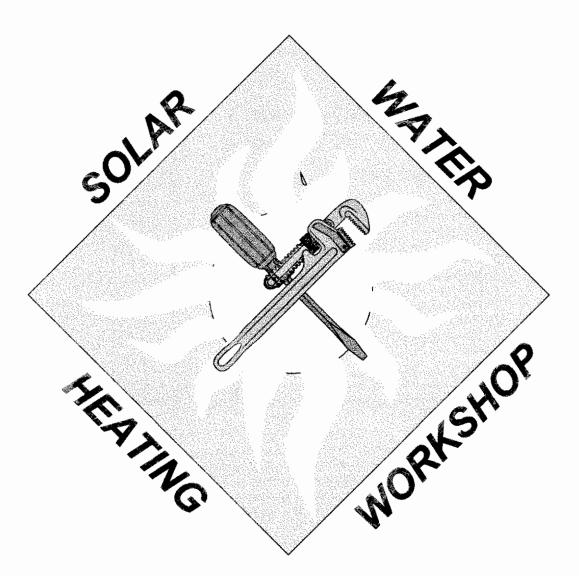


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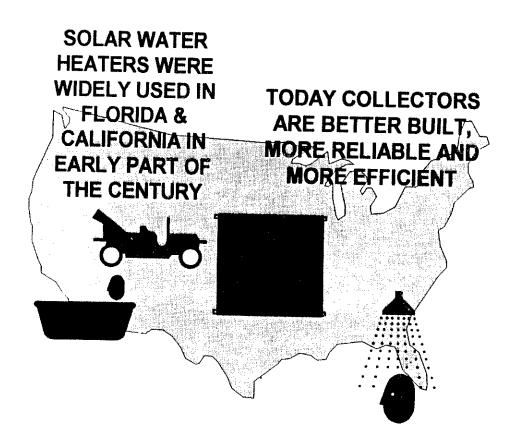
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INTRODUCTION, PURPOSE AND SCOPE:

This manual is designed to assist solar hot water heating technicians in the installation, alteration, refurbishment, service and repair of large and small solar thermal heating systems. Solar thermal systems produce heat from the sun's radiation as opposed to photovoltaics which produce electricity. Photovoltaics is only covered to the extent of supplying electricity necessary to run some types of solar heating equipment.

The manual is not necessarily written to be read from cover to cover. Although the manual follows a certain logical order from the writer's point of view, each section is written to stand alone. It is more of a reference document than a "how to" guidebook for beginners. Some basic knowledge on the part of the reader has been assumed in the preparation and layout of the basic text.

The manual was specifically designed as a reference text for workshops on solar water heating systems. Workshops that include "hands on" training as a large component of each session are recommended.



SOLAR ENERGY

Nearly all forms of energy we use today to power commonplace vehicles and appliances is stored solar energy. Oil, gas, coal, wood and hydroelectric power simply wouldn't be here without the sun. If you give any thought at all to our future on this planet, squandering valuable resources like oil, gas and coal is downright foolish. In addition to polluting our air and water these sources of energy are irreplaceable for the next few hundred million years.

Although solar space heating and hot water systems have a higher initial cost than conventional gas, oil or electric systems, they are the only systems that will pay you back. The dividend of energy savings has the added value of being untaxed. When the economics and environmental plus of solar equipment are totaled, the value of directly using the sun's energy becomes clear.

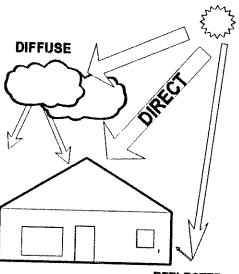
SOLAR HEATING A SIMPLE SOLUTION

Take a black sheet of metal and put it in the sun. It becomes warm, at least warmer than any light colored object around it. Now put the sheet of metal in an insulated box with a sheet of glass facing the sun. The piece of metal will get hot, about 200°F. Tilt the box so the glass is directly facing the sun and the black sheet of metal will get even hotter, 250°+F. If you now flow air or water over the black metal, you have a solar collector. The water or air is called a heat transfer fluid. Many gases and liquids can be used as a heat

transfer fluid. They are necessary to move the solar produced heat from the collector to a building, tank or pool which you desire to heat. All other aspects of solar heating and hot water are merely refinements of this simple design.

Solar collectors work best in direct sunlight. A well made solar collector produces about half the heat in light cloudy weather as it does in full sunlight. So much solar energy is blocked by the dark rain clouds that solar collectors produce virtually nothing under these weather conditions.

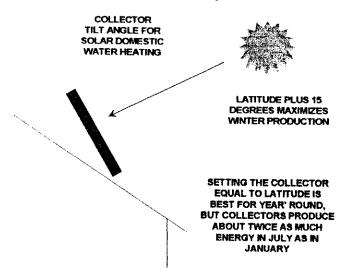
All solar collectors, outside of the tropics, produce fifty to one hundred percent more heat in summer than in winter. The summer sun is much hotter because its high position in the sky at noon is closer to perpendicular to the earth's surface. The earth's atmosphere blocks a TYPES OF SOLAR RADIATION

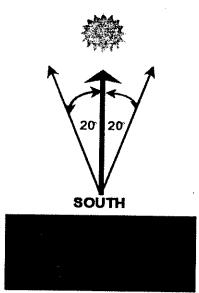


REFLECTED

large part of solar energy and the summer sun goes through less of the atmosphere. The sun is at its lowest point in the noon sky on the shortest day of the year, December 21st. or the winter solstice. Because of the extra atmosphere blocking the sunlight, solar collectors produce less heat. The colder outside temperatures also affect the collector production through heat lost through the collector back, front and sides. Because of the above factors we recommend that solar space and water heaters be tilted at an angle equal

to your location's latitude plus 15° to optimize their production of heat in the winter. Swimming pool collectors for outside pools used in the spring, summer, and fall should be tilted at an angle equal to latitude minus 15° to optimize the seasonal sun. The sun is most intense at noon every day when it is highest in the sky. The four to five hours in late morning and early afternoon are called the "Solar Window". This is when more than 80% of the total collectable energy falls on a solar collector. Collectors should face as true south as possible towards the solar window. A variation of up to 30° east or west of true south is acceptable. If the collector(s) are faced more than 30° off true south more collectors will be required. If a choice of east or west is available it is usually best to orient the collectors to the west. The outside temperatures are almost always warmer in the afternoon. Prevailing local weather patterns should also be considered in mounting the collector. For instance, if you are in an area where mornings are normally clear and afternoons are cloudy, it would be best to face the collector in a more easterly direction. A properly orientated solar collector can increase system efficiency up to fifty percent more than a haphazardly installed system.





TRUE SOUTH IS WHERE THE SUN IS AT NOON

ACTIVE SOLAR WATER HEATERS

Domestic water heating is usually the second highest energy cost for families in North America. Although solar water heaters can supply 100% of these needs, in most cases the quickest payback is realized from sizing the system to displace 50 to 90% of the load.

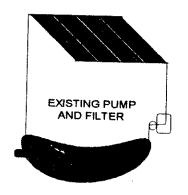
SIZING

People in the United States use an average of ten to twenty gallons of hot water per day per person. Solar water heaters are normally sized to cycle on a daily basis in the winter months and therefore the storage tank size approximates daily usage. A family of 3 to 4 will use forty to eighty gallons per day. Once an estimate of usage and tank size is determined the amount of solar collectors is calculated as follows: (The rule of thumb in the sunbelt is 1 sq. ft. of collector per 2 gallons of water.) The sizing below is not Consideration should be given to the fact that due to a number of variables (usage, climate and system installation) the sizing can be adjusted with a resulting difference in percent of the total water heating load displaced.

THREE TYPES OF SOLAR WATER HEATING COLLECTORS

LOW TEMP. UP TO 110 DEGREES F. UNGLAZED FLAT PLATE

POOLS AND SPAS



MEDIUM TEMP.
UP TO 180 DEGREES F.
GLAZED AND INSULATED
FLAT PLATE

DOMESTIC HOT WATER RESIDENTIAL COMMERCIAL





HIGH TEMP; UP TO 500 DEGREES F.+ CONCENTRATORS - TRACK THE SUN INDUSTRIAL PROCESS HEAT

VERY LARGE DOMESTIC
HOT WATER SYSTEMS
ELECTRICAL PRODUCTION



THE SYSTEMS

We recommend that only two types of active solar water heating systems be considered. A direct pump system is used in climates like Hawaii, Mexico and the Caribbean where freezing temperatures have never been recorded. If there is the slightest danger of freezing (Florida, California, Arizona and the rest of North America) the best solution is a system that uses a non-freezing liquid as the heat transfer fluid through the collectors. We have phased out the installation of other types of freeze protection systems over the past few years.

TYPICAL HOT WATER USE GALLONS

USE

1. Clotheswashing Machine (18 lb.)	
a. Hot Wash/Warm Rinse	36
2. Dishwasher Machine	15
3. Personal Hygiene	
a. Showering	3/min.
b. Tub Bathing (full)	15
c. Wet Shaving	2 to 4
d. Hair Washing	2 to 4
e. Hand and Face Washing	1 to 2
4. Miscellaneous Household Uses	
a. Washing Clothes by Hand	1 to 2
b. Washing Dishes by Hand	4
c. Preparation of Dishes	
for Dishwasher	1 to 2
d. Miscellaneous Housecleaning	2.5
e. Food Preparation	3

RULES OF THUMB

FOR ROUGH APPROXIMATIONS ONLY



COLLECTOR AREA TO STORAGE VOLUME IN SUNNY CLIMATES (SUNBELT)

SQUARE
FOOT
OF
SOLAR
WATER
HEATING
COLLECTOR

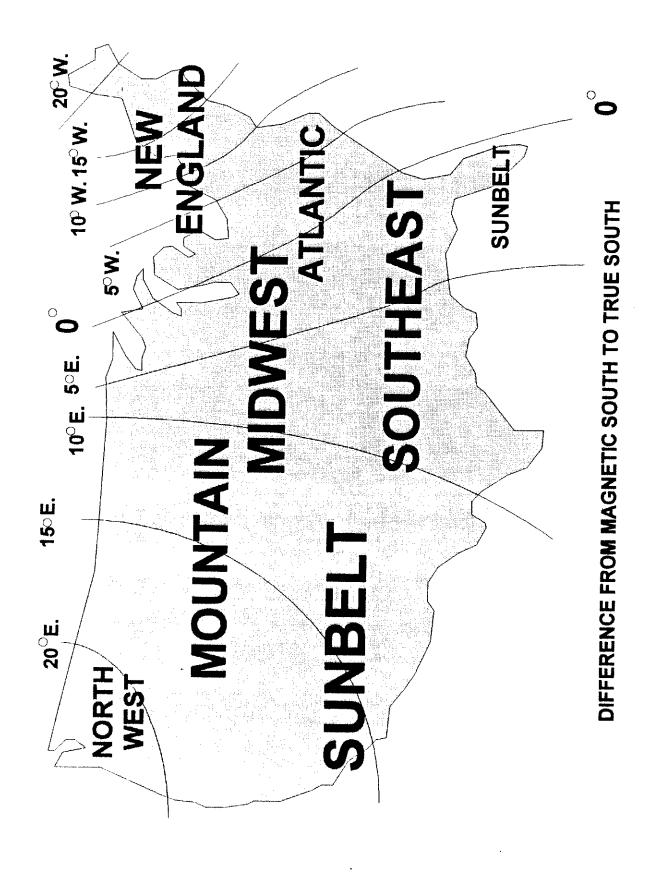


SOUTHEAST & MOUNTAIN STATES - 1 SQ. FT. = 1 1/2 GALS.

MIDWEST & ATLANTIC STATES - 1 SQ. FT.= 1 GAL.

NEW ENGLAND & NORTHWEST - 1 SQ. FT. = 3/4 GAL





LIQUID COLLECTORS

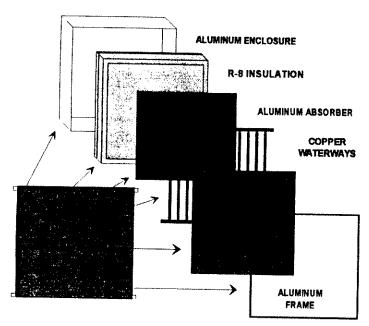
THE EQUIPMENT

The equipment for an active solar water heater consists of a solar collector(s), a hot water storage tank(s), and a pump. In addition a heat exchanger and expansion tank are required in freezing winter climates and an electrical generation device is needed if regular A.C. grid connected power is not available. Piping, insulation, valves and fittings are considered installation materials and are normally available at hardware stores and home centers.

A good liquid solar collector should have a minimum life expectancy of 20 to 30 years. Most of the collectors built since about 1980 are manufactured with materials that should give thirty to fifty year lifespans with a small amount of periodic maintenance.

All good liquid collectors have copper water ways (piping & tubing), tempered glass glazing and an insulated metal enclosure.

MEDIUM TEMPERATURE COLLECTORS



- a. Copper water tubes and headers in the collector are a must if water or any water solution is to be used as the heat transfer liquid. Aluminum and steel tubes have been used in the past with silicone or oil transfer fluids but these metals are not suitable for long life in a liquid collector if water is used. To our knowledge all glass glazed liquid collectors made today use copper waterways. Α liquid collector under no flow or stagnation conditions can attain temperatures of 250 to 300°F. **Plastics** other silicone or teflon are not suitable
- b. The absorber plate is made of copper, aluminum or steel and bonded to the waterways. The plate surface is approximately equal to the glazing surface and is painted or anodized with a black paint or selective coating. A selective (black nickel or black chrome) surface on the absorber increases the collector output by limiting reradiated heat (emittence) from the absorber. The method used to bond the plate to the absorber is an important consideration. The better bonding, the higher the output. Simply wiring or clamping the tubes to the plate will produce discouraging results.
- c. Glazings on collectors today are almost exclusively low iron tempered glass. The iron content of regular window glass stops about 17% of the light passing through it.

Low iron glass limits this loss to about 10% and increases the output of the collector proportionally. Solar collectors are normally tilted and subjected to the outside elements, consequently tempered glass is needed if the collector is to survive the first hail storm. Tempered glass (also used in patio and shower doors) resists breakage many times better than regular annealed window glass.

d. The sides and back of the solar collector which do not face the sun should be insulated to prevent heat loss and covered in a weather tight enclosure. Enclosures in the past have been constructed of wood, fiberglass, plastic, aluminum or steel. Virtually all enclosures for collectors manufactured today are made of aluminum due to its outstanding weatherability. Insulation used is either fiberglass or polyisocyanurate, both of which can withstand temperatures in excess of 400°F. Styrofoams by comparison are unsuitable because they start degrading at about 170°F, well below collector stagnation temperatures.

TYPES OF ABSORBERS FOR MEDIUM TEMPERATURE FLAT PLATE COLLECTORS (ALL ARE SIDE VIEW CUTAWAYS)



CONTINOUS

THE MOST WIDELY USED DESIGN BOND
COPPER OR ALUMINUM PLATE BONDED TO
COPPER TUBE WATERWAYS
(SOME MANUFACTURERS HAVE FLATTENED THE
TUBES, SOME HAVE WRAPPED THE PLATE AROUND
THE TUBES - TUBES ARE NORMALLY SPACED
FROM 2" TO 6" ON CENTER ON THE PLATE



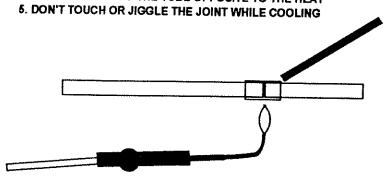
ROLL BOND TYPE PLATE MADE FROM TWO SHEETS
OF COPPERWHICH ARE BONDED AND THEN EXPANDED
UNDER PRESSURE TO FOR THE WATERWAYS

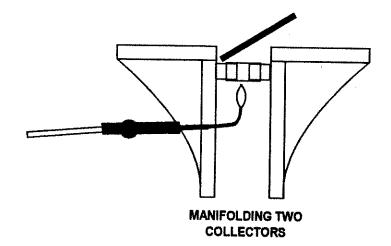
TRICKLE DOWN PLATE MADE FROM CORRUGATED ROOFING

SOLDERING AND BRAZING COLLECTORS

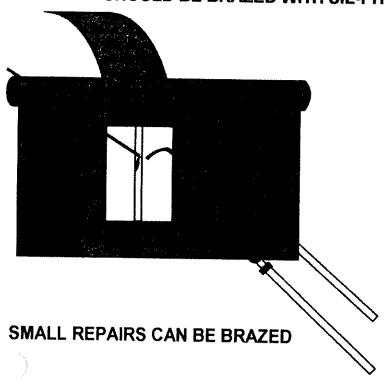
FIVE STEPS TO SUCCESSFUL SOLDER JOINTS

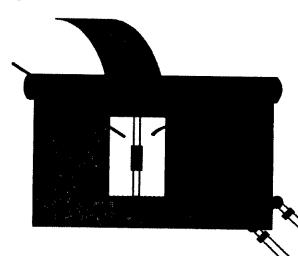
- 1. CLEAN THE TUBE AND FITTING WITH WIRE BRUSH
- 2.USE A GOOD FLUX TO FLUX THE FITTING AND TUBE
- 3. APPLY HEAT TO THE FITTING
- 4. APPLY SOLDER TO THE TUBE OPPOSITE TO THE HEAT





ALL REPAIRS INSIDE COLLECTORS SHOULD BE BRAZED WITH SIL-PHOS





LARGER LEAKS SHOULD HAVE A COUPLING TO REPAIR THE TUBE

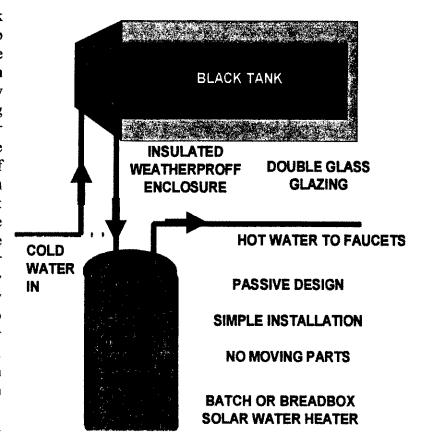
PASSIVE BATCH SOLAR WATER HEATERS

Passive solar water heaters contain no mechanical moving parts. Passive water heaters come in four types: Batch or breadbox heaters, thermosyphon heaters, freon type heaters and the new "geyser" water heater. Many companies have experienced numerous problems with freon type systems and we do not recommend their installation. The "geyser" type system is new and due to its operation under a vacuum, it is very difficult to install.

BATCH OR BREADBOX SOLAR WATER HEATERS

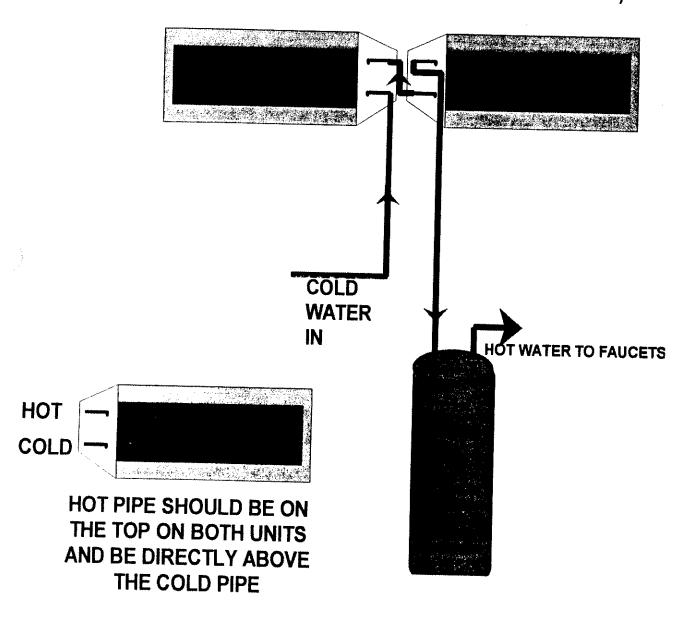
Batch water heaters are the simplest of all solar water heaters. These are also known as integral tank and collector heaters. Batch water heaters use tanks between 30 and 80 gallons. The tank is placed within a weatherproof, insulated enclosure with one side having a transparent or translucent glazing(s), normally two layers of glass. The side of the tank facing the glazing is painted black to absorb the solar energy which is conducted directly to the water in the tank.

Batch solar water heaters work great in the tropics. Due to winter nighttime heat losses we do not recommend them in climates above approximately 35° N. latitude. The only thing on one side of the collector between the hot tank and the cold outside air is 2 layers of glass. In climates harsher than this, the heater tends to lose at night most of the daytime energy gained throughout the winter months. Batch water heaters are simple, reliable, easy to install and are typically low cost. They can provide fifty to ninety percent of hot water needs depending on usage and climate. The piping to and from the heater is the weak link in the chain. It should be well insulated and heat tape should be installed in harsh climates.



BATCH OR BREADBOX SOLAR WATER HEATER SERIES PIPING

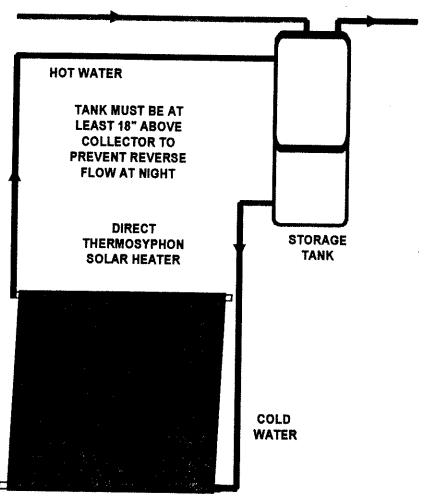
BOTH UNITS SHOULD BE FACED AS CLOSE AS POSSIBLE TO TRUE SOUTH (NORTH IN SOUTHERN HEMISPHERE)



THERMOSYPHON SOLAR WATER HEATERS

Thermosyphon solar water heaters use the natural convection of liquids to collect the solar energy. Liquids expand upon a rise in temperature and, therefore, the heated liquid is lighter than the same cold liquid. With the proper design and installation techniques, it is possible to achieve efficient flow rates through the system without using a pump. Thermosyphon systems must be configured with the storage tank above the collectors to work effectively.

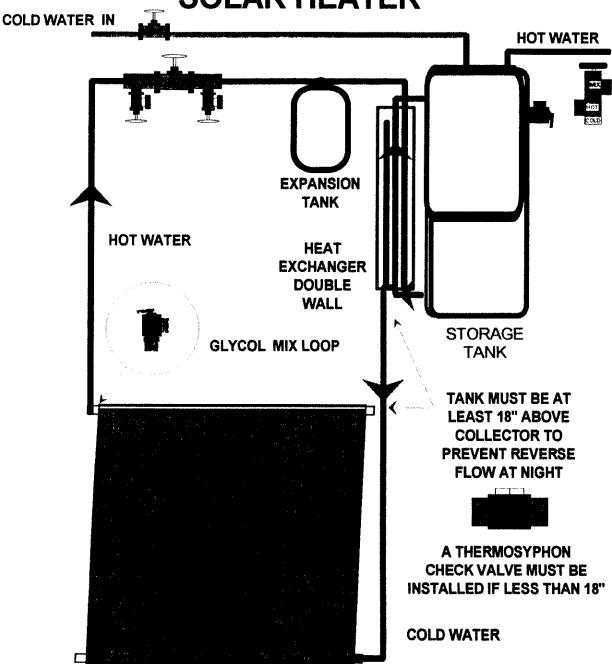
direct Α thermosyphon system uses tap water as the medium of heat transfer. The collectors and tank are of the same type used in active solar systems. When the sun heated water in the collector starts moving due to natural convection, it is piped to the top of the storage tank. The colder water in the bottom of the tank flows to the bottom inlet of the collector. The system does not require a control and will not cycle backwards at night if the tank is at least 18" above the collector. The use of a passive check valve in the system will prevent reverse thermosyphoning if the tanks hot water inlet is above the collector outlet and the tanks cold water outlet is above the collectors cold water inlet. This allows the

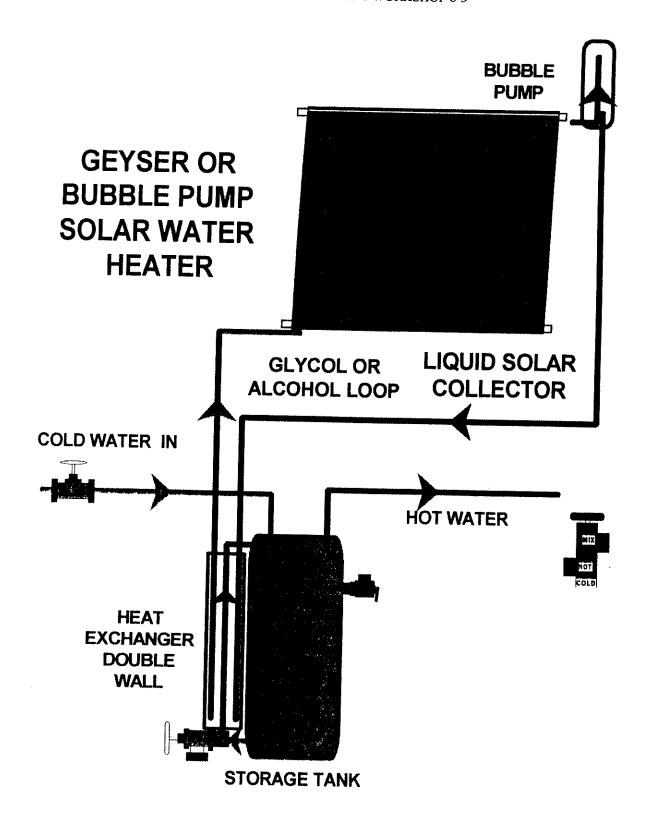


tank to be just slightly (1/2") above the collector and increases the installation possibilities. These systems cannot be installed outdoors in freezing climates. In freezing climates a thermosyphon system can also be configured as a glycol loop system by employing a tank and heat exchanger. In this system, the glycol solution (50% propylene glycol and water) is the transfer medium between the collector and the tank through the heat exchanger. As the collector glycol solution is heated, it moves by natural convection to the top of the heat exchanger, transferring the energy to the water in the storage tank. The colder glycol solution at the bottom of the heat exchanger, which is heavier, flows to the bottom inlet of the collector. The same equipment placement rules of direct thermosyphon systems apply

(tank above the collector). Thermosyphon systems are very reliable with no operating costs, but glycol thermosyphon systems are somewhat inefficient due to the low flow rates in the two convective (thermosyphon) loops.

GLYCOL THERMOSYPHON SOLAR HEATER





DIRECT PUMP

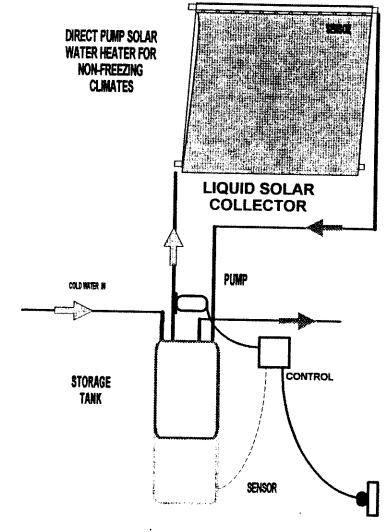
A direct pump system circulates tap water through the solar collector(s). These systems were first developed in the late 19th century and were in wide use up to the 1920's in Southern California and Florida. The systems are called open loop and are very simple, efficient and reliable. A single low head (3' to 12') pump circulates the storage tank water through the solar collector. The water is piped from the bottom or coldest part of the tank to the pump, then to the collector and back to the top of the tank.

In alternating current (A.C. or house current) systems the pump is controlled by a differential control. The control constantly monitors the tank temperature and the collector temperature and turns the pump on when the collector is hotter than the tank water. When the collector is no longer hotter than the tank the control shuts the pump off providing complete automatic operation.

Direct current (D.C., usually provided by Photovoltaic systems) normally do not need a control if the pump, P.V. module and collector are properly sized. If there is enough

sunlight for the P.V. module to run the pump then the collector should be hot enough to heat the tank water. When the sun goes down and the collector cools, the P.V. panel stops generating electricity to the pump.

Periodic maintenance is required if hard water with high mineral content circulated through the collectors. If this is a possibility provisions should be made upon installation to be able to circulate a mild acidic solution (vinegar or intech 52) through the collector every three to five years to remove the mineral build up.



GLYCOL SYSTEMS

The majority of people in North America and the world live in climates where freezing temperatures are at least a possibility. Solar collectors are normally installed outside and copper tubes are subject to bursting when water freezes and expands. This alone makes untreated water unsuitable as a heat transfer fluid in solar collectors. Ethylene Glycol, Propylene Glycol, Silicone Fluid and a variety of oils have been used successfully in the past as heat transfer fluids. The lower specific heat (ability to hold heat) of silicone and bray oil and their limited availability and high price discourage wide usage today. Ethylene Glycol, better known as car antifreeze, is a good choice except for its toxicity. We prefer a fifty percent solution of non toxic propylene glycol and water as a heat transfer fluid in freezing climates.

A glycol system contains two entirely separate piping systems which are called loops. The two piping systems or loops are connected through a device called a heat exchanger. A simple, economical heat exchanger can be constructed of a 1/2" copper pipe inside a 3/4" copper pipe. If the hot glycol solution is made to flow through the larger tube and cold water through the smaller, the heat will be exchanged and the water heated. This is called a single wall heat exchanger. Single wall heat exchangers are prohibited by the national plumbing code since breaching one pipe could possibly contaminate the domestic water loop if the glycol loop contained a toxic fluid. All glycol systems should have a design where two pipe walls must fail in order for the glycol loop fluid to mix with the potable (drinkable) water system. Although double wall heat exchangers are more complex and expensive, they should always be used in these systems.

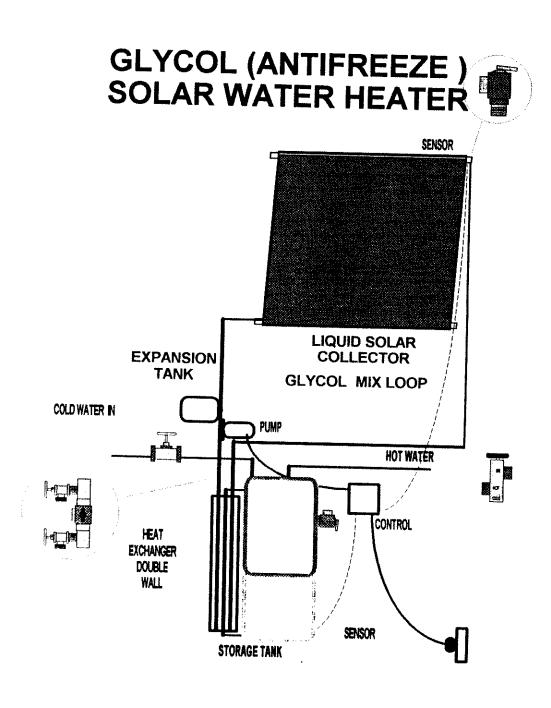
A low head pump (3' to 12') is used to circulate the glycol solution. The water in the DHW (Domestic Hot Water) loop can be circulated through the heat exchanger with another low head pump or configured to thermosyphon. Thermosyphoning uses the physics that hotter liquids are lighter and will naturally rise. If the heat exchanger inlet connection can be placed and connected under or near the bottom of the storage tank and the outlet piped to the top of the tank the water will thermosyphon through the heat exchanger. The water will only flow if it is being heated by the glycol loop.

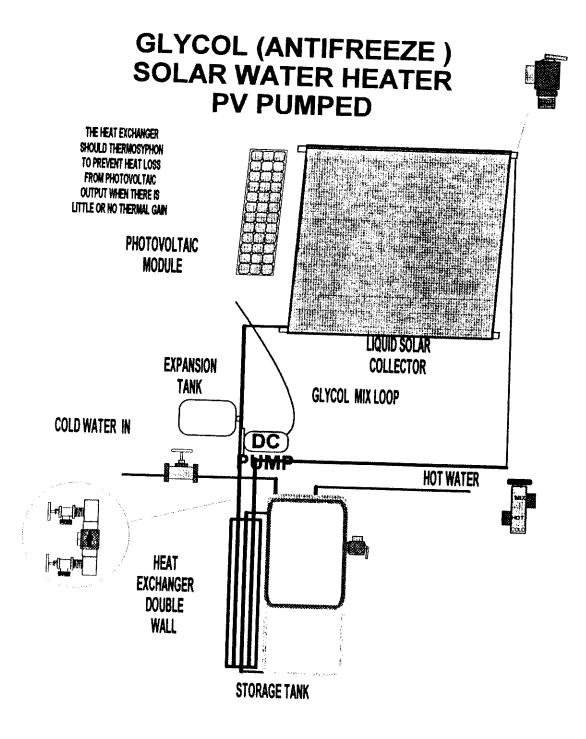
When any liquid is heated it expands physically. In open loop systems this expansion is not a problem since the extra pressure is absorbed through the entire piping system in the house, well system or city water system. The glycol loop is closed and an expansion tank of the proper size is required to prevent excessive pressure in the loop.

A differential control is needed if two pumps are used in the glycol system. If the system can be installed with a thermosyphon DHW loop a simple snap disc switch or light sensing switch will normally be workable. If P.V., D.C. power is used with a D.C. pump(s) and the components are sized correctly a control is usually not necessary.

Periodic maintenance of glycol systems must address two things, the condition of the glycol and the hardness of the domestic water. Glycol solutions can turn acidic after a few years of use. The solution should be checked with Litmus paper or a P.H. meter every three to five years. Acidic glycol solutions should be drained, purged with water and refilled with a new solution. Acidic solutions are usually caused by overheating the glycol

loop above 225°F. If the solar system is not used for an extended period of time, the collector loop should be drained and the fluid stored or the collector glazing should be covered. If hard water with high mineral content is circulated through the DHW loop, the tubes in the heat exchanger will eventually clog. This should be checked every three to five years depending on water hardness and corrected with a light acidic solution (vinegar or intech 52) circulated through the tubes until the deposits are gone. A heat exchanger that can be taken apart can be cleaned with a wire brush. A correctly designed solar water heater of this type can produce hot water in virtually any climate for decades.



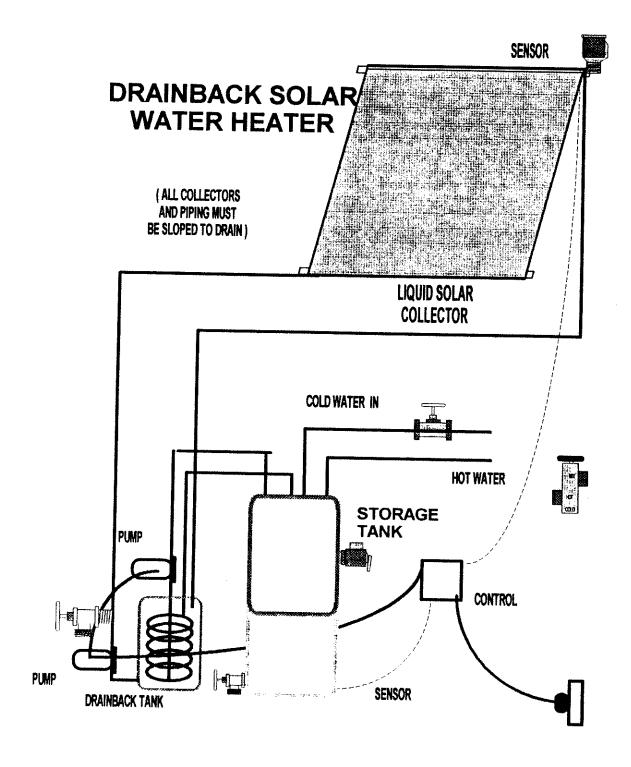


DRAINBACK SYSTEMS

Drainback systems are one of the most reliable types of solar systems and offer a wide range of flexibility. The collectors in a drainback system are filled only when the differential controller has sensed the proper temperature difference between the collectors and tank. The controller energizes a "high head" pump. This pump must be able to overcome the atmospheric air pressure in the vertical length of piping between the pump and the top of the collectors (head). The water that is circulated to the collectors is stored in a drainback reservoir (unpressurized tank). Drainback tanks come in sizes from eight gallons to thousands of gallons, depending upon application. The three types of drainback systems in wide use today include the one pump DHW, two pump DHW and multi-pump DHW/space heating system. One pump DHW systems consist of collectors, controller, high head pump and a drainback tank (typically 8 to 20 gallons) and a pressurized solar storage tank with an internal heat exchanger. The controller, upon sensing the proper differential, energizes the high head pump which circulates water (diluted) from the drainback tank to the collector's and then to the heat exchanger located inside the storage tank. The heat exchanger (a loop of copper tubing) is immersed in the pressurized water and transfers the solar energy from the unpressurized collector loop to the DHW system. When the collectors drains back into the drainback tank. The collectors have been tilted properly upon installation to accommodate draining.

A two pump drainback is similar to the one pump, but the heat exchanger (once again, a loop of copper tubing) is in the drainback tank and is pressurized. When the high head pump is energized, water from the drainback tank is circulated to the collectors and back to the tank. The pressurized heat exchanger is immersed in the unpressurized water in the drainback tank. A second, every small pump (1/100 to 1/50 HP.) is energized simultaneously with the high head pump and circulates the pressurized water to the storage tank. Although this system is slightly less efficient than the one pump system (due to the extra pump and a less efficient heat exchange), this system can have a lower initial investment due to the higher cost of storage tanks with internal heat exchangers.

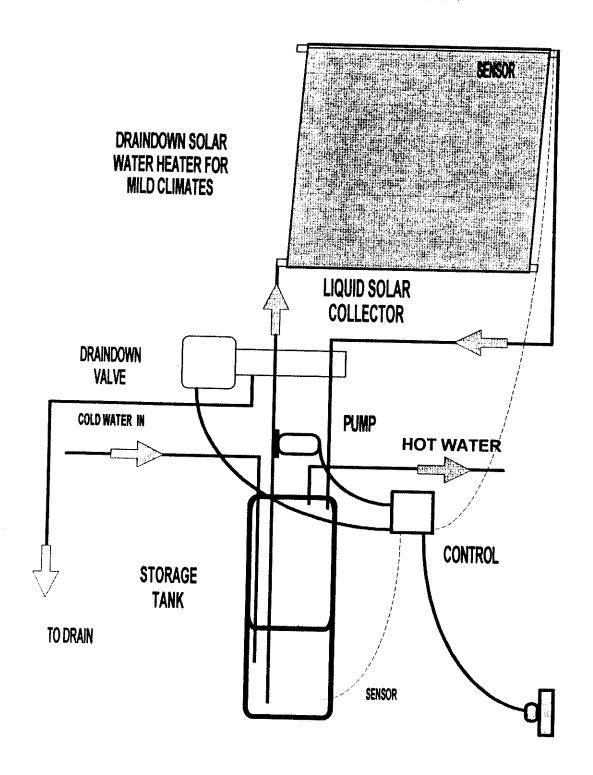
A multi pump/multi use system normally has a large drainback tank (from a few hundred to thousands of gallons). As in the other drainback systems, the tank, high head pump and collectors are subject to atmospheric pressure only (unpressurized). The pump is again energized when the proper differential is achieved and the large tank is heated by the collectors. One or more heat exchangers (coils of copper tubing) are immersed in the tank and auxiliary pumps with separate controls can be used to heat DHW, swimming pools or spas. The unpressurized water in the tank may also be used directly for space heating through fan coil units or integrated in some cases with the conventional back up heating system (i.e., a liquid to air heat exchanger in the forced air ducting system).



DRAINDOWN SYSTEM

Draindown systems were installed in great numbers throughout the United States in the late 1970's and early 80's. A draindown system has the high efficiency of a direct pump system (one low head pump and no heat exchanger) and what seemed like a good idea for freeze protection. As in a direct pump system, the collectors are filled using existing water pressure and a differential controller is used to energize the pump by sensing a difference in temperature between the collectors and storage tank. A draindown differential controller also monitors a number of freeze sensors (two or three normally) which are placed near the collectors and on the outdoor piping system. When the outside temperature dips below approximately 40° F, one or all of the freeze sensors open the circuit to the draindown valve, and the collectors (which have been tilted slightly upon installation) drain into the pressure relief piping of the hot water tank. The draindown valve is spring actuated to draindown if not energized. Upon the freeze sensors rising to approximately 50° F, the circuit is closed, awaiting the proper differential for pump circulation.

If the draindown valve fails to draindown upon being deenergized and the temperature falls below freezing, there is a good chance the ice will burst the tubing in the collectors and piping system. It is not uncommon for the draindown failure to render a collector, or entire arrays of collectors, uneconomically repairable. If you choose to install a draindown system, you must be prepared to monitor the draindown mechanism during the cold months and service the valve on a periodic basis. A new draindown control is now available that cycles the valve more often. It has features which help to prevent many of the failures of the past. These systems are normally used for domestic hot water (DHW) only.



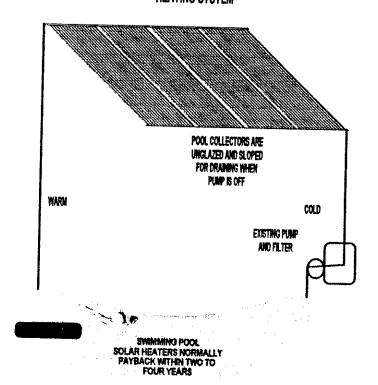
SWIMMING POOL SYSTEMS

Swimming pool collectors are designed for outdoor pools. In most of the country outdoor pools are used six to nine months of the year. Pool collectors are normally made of polypropylene, a high temperature plastic that can consistently operate in the 200°F range. The collectors are black in color and should normally keep a pool in the 80°F range throughout the pool season. The same pump that filters the pool is used to circulate pool water through the collectors. A quick rule of thumb for pool design sizing is one square foot of collector surface area to every two square feet of pool surface area. This can give you a good idea of

how large a pool system is required. You will need more collector surface area if your pool is left uncovered. especially in the spring and fall. The pool collectors should face within 30° of true south and are tilted at an angle of latitude minus 15° from horizontal.

Virtually all of the pool systems we install today use a simple mechanical timer to control the pump. You simply filter and heat the pool during daylight hours.

SOLAR SWIMMING POOL HEATING SYSTEM



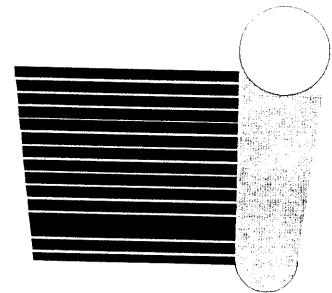
Outdoor pool systems probably have one of the quickest returns on your investment of any solar energy equipment. In most cases it is simply foolish not to consider heating an outdoor swimming pool with solar energy.

Most swimming pool systems we install are controlled by a timer. Since most pools already have a timer for filtering, the time need only be set for daytime hours and pool water diverted to the solar collectors. Use of the optional differential controller and motorized flo-verter valve optimizes system efficiency but, in most cases, we feel it is not necessary.

POOL COLLECTOR ABSORBER PLATE DESIGN

HEADER. TYPICALLY 1 1/2"
TO 2"

RISER TUBES TYPICALLY ABOUT 1/4"



TYPICAL POLYPROPYLENE COLLECTOR (NOT MADE FOR INSULATED, GLAZED ENCLOSURES)

COPPER WATERWAYS (HEADERS AND RISERS)

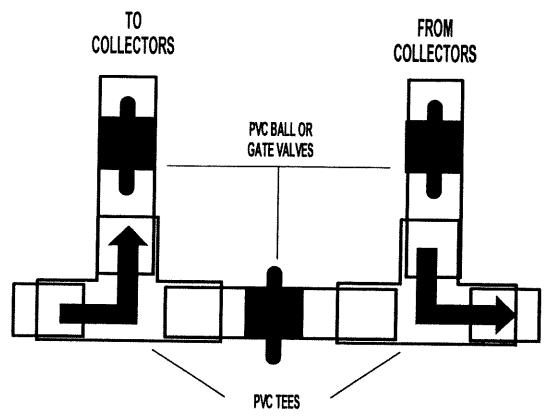


ALUMINUM OR COPPER PLATE

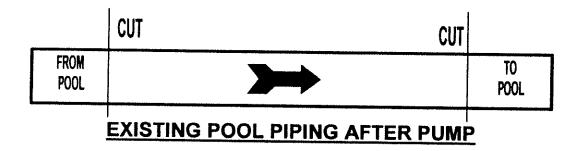


CONTINUOUS SOLDER, BRAZE OR ADHESIVE BOND

TYPICAL METAL POOL COLLECTOR

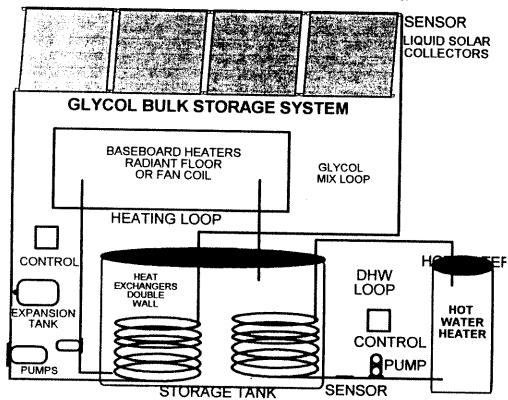


POOL PIPING AFTER MODIFICATION



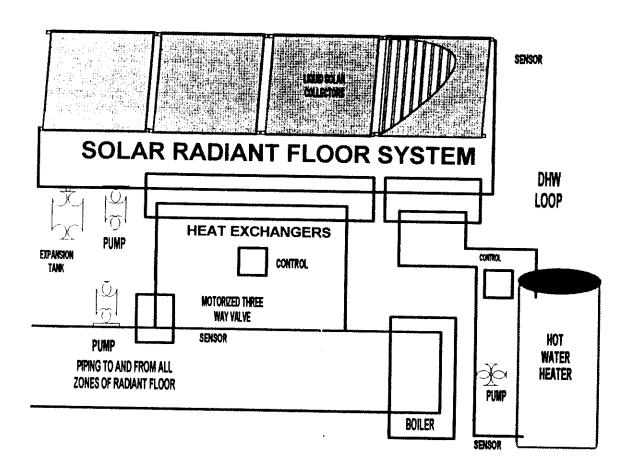
HOME SPACE HEATING SYSTEMS USING LIQUID COLLECTORS

A space heating system using liquid solar collectors can provide fifty to seventy five percent of the energy needed to heat a house in the winter. A large (400 to 2000 gallon) tank is needed to store the heat gained in the day for nighttime use. These systems are called bulk storage in reference to the large tank. Most of the bulk storage systems in use today circulate the water in the large tank through the solar collectors. The collectors are tilted slightly upon installation and the water is drained automatically from the collectors when the pump is off to prevent collector freeze-up. This is called a drainback system. After numerous freezes due to clogged piping, damaged piping and control failures, we no longer consider a drainback system to be a sure enough method for freeze protection. Bulk storage systems that we recommend use a fifty to one hundred foot copper tube coil in the tank to exchange the heat from a glycol solution circulating through the solar collectors. The coil of tubing immersed in the tank effectively heats the tank water in a closed loop. The tank water is then plumbed to a fan coil, heater or the home's heating system. A solar system of this type can be integrated with radiant floors, baseboard radiators or forced air furnaces. A second coil of tubing, typically 1/2" copper can be submerged in the tank for heating domestic water. This provides the code required double wall of protection between the collector loop and the DHW loop. The system is sized to keep the tank between 100 to 160°F during sunny days. Completely automatic controls heat the house upon the call of the regular heating thermostat as long as the water is hot enough. When sufficient heat is no longer available in the solar bulk tank, the controls automatically allow the conventional boiler or furnace to heat the home.



Radiant Floor Systems

The exception to the large tank for home heating with liquid collectors is a radiant slab floor. Radiant floor heating systems have a history going back to the Roman Empire. Due to their higher initial cost these systems have only recently experienced a comeback in popularity. A well designed radiant floor system distributes heat evenly over the entire floor area where you want and need it the most. If the piping that carries the water in a radiant floor system is encased below a 4" slab of concrete, chances are you can heat the home with a solar heating system minus the bulk storage tank. You can still realize a 50 to 75% reduction in conventional energy costs. A rise of 10°F in a concrete slab is the rough equivalent of a 40° rise in a 400 gallon tank. Most radiant floor heating systems have a "lag time" of from three to twelve hours due to the slab soaking up the heat prior to it being felt in the house. This lag time works very well with the solar energy stored, as the heat collected at noon may not be "felt" until after dark in the winter. A properly sized heat exchanger and a three way motorized valve with the proper controls are all that is required to integrate the solar collectors with the radiant floor. A second smaller double wall heat exchanger may be added to heat the domestic hot water as explained on page 6. This type of system needs a large expansion tank to prevent over pressure during the summer months unless the heat generated by the solar collectors does some other job, such as heating a swimming pool. Periodic maintenance is the same as given in active hot water heaters.

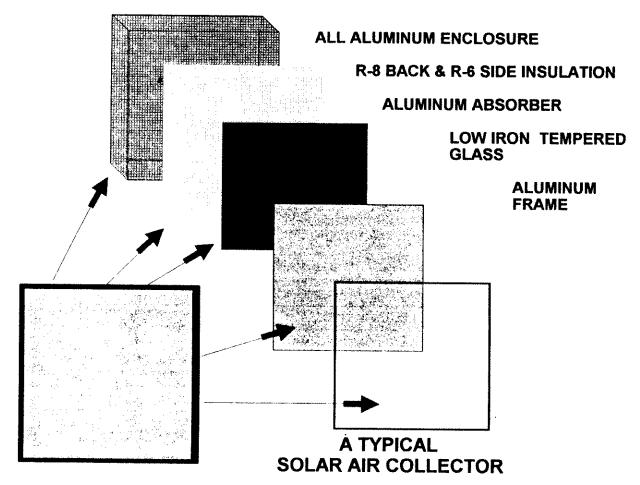


Solar Air Collector Systems

Solar air collectors are similar in operation to liquid collectors with one major exception. Air is circulated through the collector and is the medium of heat transfer. Since air will not freeze under any normal circumstances on the planet, all of the techniques and equipment needed to protect liquid systems can be ignored. Air collectors are being used successfully today for such diverse applications as composting toilets, heating water and benzene removal from the earth. Their main functions are for solar space heating of homes and buildings.

The Collectors

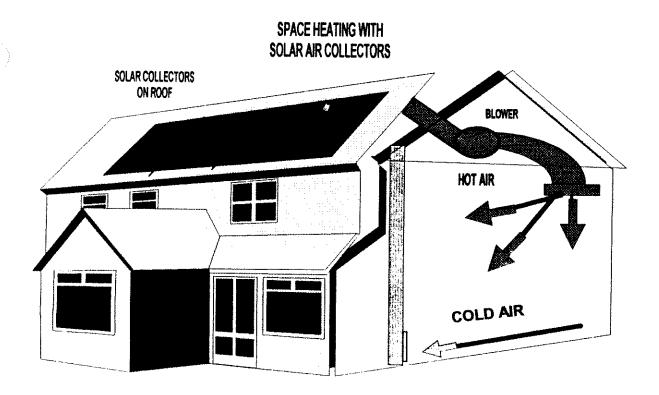
When solar air systems started becoming popular in the late 1970's, most collectors were of questionable construction, with efficiencies of 40 to 50%. By 1985, efficiencies had risen to 60 to 70% and collectors were built with life spans up to fifty years. All high quality air collectors today have three things in common: an enclosure made of aluminum or steel, insulation on the back and sides and low iron, tempered glass glazing on the front. Collectors normally have a single glazing with a dead air space between the glass and the absorber plate. Absorber plates are made of aluminum, steel or copper. The plate is coated on the side facing the sun with black paint or a selective surface process. Selective surfaces (black chrome) increase efficiency by limiting reradiated energy back through the glazing. Air collector absorber plates should be dimpled or corrugated to create air turbulence that helps "wash" the heat from the plate.



Blowers and Controls

When installed properly a 4 foot x 8 foot air collector can provide 25 to 50% of the energy needed to heat a 400 to 800 square foot space depending on climate and building construction. This makes air collector systems ideal for zone type heating systems. Installers normally use a separate blower, control and ducting system for every 32 to 64 square feet of collector area. The blower pulls air from the cold air inlet of the space through the collector and blows the heated air back to the hot air outlet. Optimum performance is achieved with a squirrel cage blower of approximately 200 to 400 cubic feet per minute of air flow. Smaller blowers can be used and performance is slightly effected, but they must be of a squirrel cage configuration.

The system is controlled by a simple, reliable bi-metal switch in the collector which turns the blower on at 110° and off at 90°. This gives automatic operation with each sun cycle. An interior thermostat or manual switch wired in series with the bi-metal switch allows the occupant to "call for heat" or shut the system off when heat is not required. The system is completed with the addition of a backdraft damper in the duct system to prevent nighttime cooling from thermosyphoning.



Air Movement

Hot air rises and cold air falls. This concept of air movement, called natural convection, is important in any space heating project no matter what fuel is used. Wood stoves are superior to fireplaces in heating mainly because the stove causes a convection current of air throughout the room or building. Most fireplaces only radiate heat into the immediate area. Although this concept is ignored in designing many modern fossil fueled heating systems, it is an integral part of all

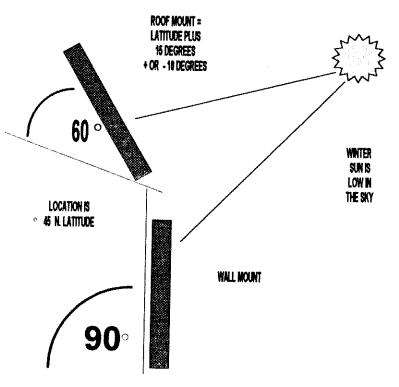
successful solar heating installations. If a solar heating system works with natural convection, hot air rising and cold air falling, then the result in comfort level can exceed expectations.

The Installation

Almost everyone today only lives in half their house - the bottom half. We need heat the most when the weather is cold and we are sedentary (sitting lying down). In building with little air movement the air tends to stagnate or stratify. Air temperature rises approximately 1°F. per foot. The ceiling of an A-frame house can be 20 to 25° hotter than the floor. Any good space heating system designed around the fact that we live near the floor and the heat is at the ceiling.

The cold air inlet to the heating system is the key to

COLLECTOR TILT ANGLE FOR SOLAR SPACE HEATING



efficiency and comfort. To heat any given space, the cold air must be removed and circulated through the heater; therefore, the inlet must be ducted so it is on or near the floor. If the inlet is placed on the ceiling, the heater will tend to recirculate the hot air and leave the floor cold. The hot air supply may be placed at the ceiling or on the floor with little difference in performance. If placed on the floor, the hot air rises to the ceiling within a short distance. Since collectors are normally installed on the roof of the building being heated, it is best to place the hot air outlet in the ceiling to shorten the duct run. A system installed in this manner de-stratifies, or mixes, the air in a building like a ceiling fan, in addition to supplying solar heat.

Orientation

The orientation of air collectors for heating in the winter is the same as given for liquid collectors. The collector should face within 30° of true south and tilted at an angle of latitude plus 15°. The exception is that many air collector systems for space heat only are mounted on the south building wall and have a tilt of 90°. These systems have good efficiency if they are used for space heating.

Energy Storage

The main niche for air collectors in the solar industry is supplying 25 to 50% of required energy for space heating. Additional storage is not required in most cases. A normal, well insulated house has enough interior mass alone to store enough heat for three to four hours after sundown, if the temperature is raised 10°F. (ie., 68° starting, 78° ending). More massive construction, such as adobe or brick, can store even more thermal energy. Due to their complexity, large rock and water storage systems are rarely cost-effective. They often require extraordinary maintenance.

The best features of air collector systems are simplicity and reliability. The collectors are relatively simple devices. A well-made blower can be expected to have a 10 to 20 year life span if properly maintained, and the controls are extremely reliable. Since air will not freeze, no heat exchanger is required. By using packaged insulated flex duct, the installation can be accomplished by anyone with a little mechanical ability. All this adds up to a quick payback on the cost of the equipment and gives you years of warmth with safe clean solar heated air.

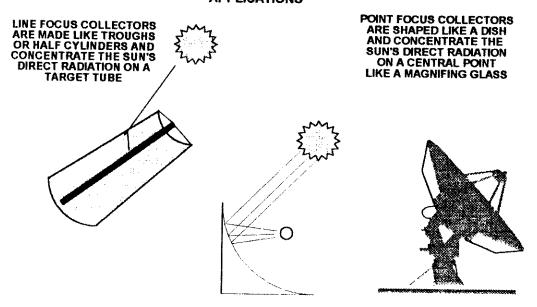
COMMERCIAL - INDUSTRIAL SYSTEMS

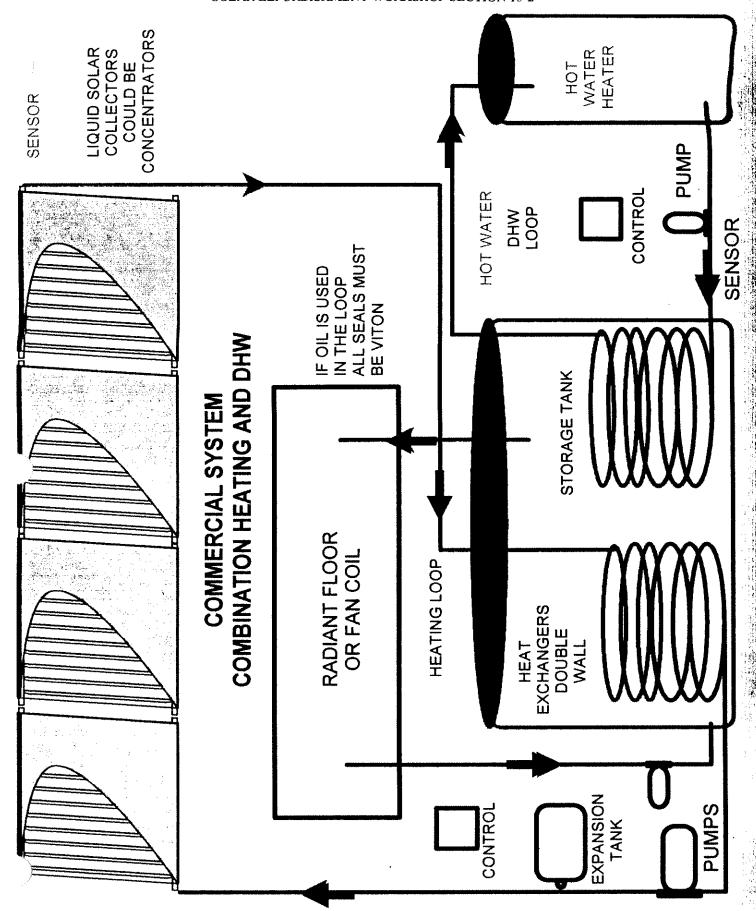
Commercial and industrial solar heating systems tend to be very large. All systems of this type were probably designed by a professional engineer and will have drawings specific to the individual system. When looking at large systems be prepared to find system equipment very large. Sometimes heat exchangers are as big as a room and tanks as large as a building. Many tanks are buried underground. Piping and insulation alone can cost tens of thousands of dollars in large commercial systems.

THE COLLECTORS

Commercial and industrial systems often use solar concentrating type collectors to capture the sun's energy. They may also be of the flat plate design. All of the systems will probably be identifiable as one of the designs given in previous sections.

BOTH OF THESE TYPES OF COLLECTORS ARE CAPABLE OF 500 DEGREE F. PLUS TEMPERATURES AND ARE USED IN COMMERCIAL INDUSTRIAL APPLICATIONS

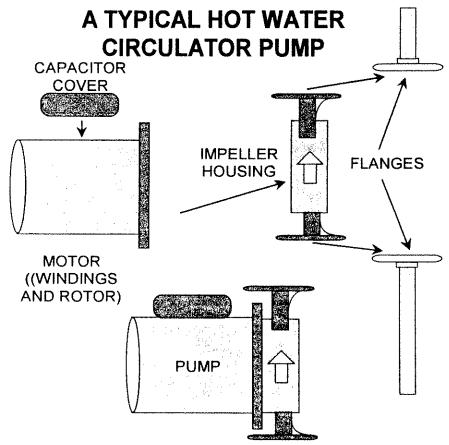




PUMP HEAD AND FLOW RELATIONSHIPS

Pumps

The wetted components of pumps used for moving water are normally constructed from bronze or stainless steel. These materials do not deteriorate in water, do not contaminate the water, and are compatible with the other piping system materials normally used. No special seals or gaskets are required. Pump components in contact with non-freezing solar fluids are normally made of cast iron or steel. Special gaskets and seals are always required. For applications requiring a small (1/35 to 1/2 HP) circulating pump, the typical unit is a "wet rotor" type. The moving part of the pump motor, the rotor, is surrounded by water. During operation, part of the water being pumped acts as a lubricant and coolant for the motor. Wet rotor pumps require no other lubrication or maintenance, other than periodic inspection. Larger systems may use a number of small wet rotor pumps ganged together, but the usual choice is one large pump of traditional design. Because the motor and pump are physically separated, periodic lubrication is usually required, and inspection procedures include checking for shaft alignment and bearing wear.



PIPING CONNECTIONS ON CIRCULATORS INCLUDE FLANGE FITTINGS, UNION FITTINGS, SWEAT FITTINGS AND PIPE THREAD

Pumps and Flow Rate

If the system controls are working correctly, an inoperative pump may be due to a stuck impeller, a burned-out motor, or a broken shaft. These types of problems may be expected over the lifetime of any component subjected to the temperature and cycling stresses of a solar system pump. Even though a solar pump is operating and is being controlled correctly, there still may be problems with the actual flow rate in the collector loop. If the pump has been sized to just barely overcome the pressure head of the collector loop, an unexpected added resistance can stop all flow through the collector. For example, air in the fluid may, over a period of time, collect in a section of piping, especially if it cannot escape through a vent to the atmosphere. This "air lock" can prevent any flow if the pump does not have the capacity to compress the air completely and force it through the system. In an indirect system, loss of collector fluid pressure can also prevent flow in the collector loop. The pump is generally not sized to overcome the static head or pressure due to the difference in height between the top and bottom of the collector loop. It is usually sized to maintain the desired flow against the dynamic head or pressure due to the resistance to flow in the pipes, fittings, and valves. If the fluid pressure to overcome the static head is lost, then the pump may not be able to maintain flow against the combined static and dynamic head of the system.

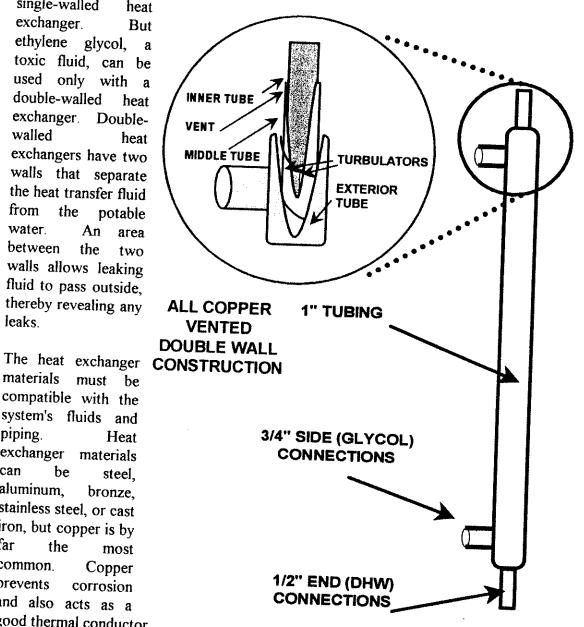
Heat Exchangers

Heat exchangers are used in indirect systems to transfer the energy collected at the solar collector to the water in the storage tank. Heat exchangers are either internal or external to the storage tank and their construction is either single or double walled. Whether a single or double walled exchanger is used depends on the type of fluid used.

Non-toxic fluids such as propylene glycol can be used with a single-walled exchanger. But ethylene glycol, toxic fluid, can be used only with a double-walled heat exchanger. Doublewalled heat exchangers have two walls that separate the heat transfer fluid from the potable water. An area between the two walls allows leaking fluid to pass outside, thereby revealing any leaks.

materials must be compatible with the system's fluids and piping. Heat exchanger materials can be steel. aluminum, bronze. stainless steel, or cast iron, but copper is by far the most common. Copper prevents corrosion and also acts as a good thermal conductor.

DOUBLE WALL HEAT EXCHANGERS



SOLAR REFURBISHMENT WORKSHOP SECTION 15-2

Heat exchangers used in solar heating systems are typically one of three types:

- o Tube-in-tube
- o Coil-in-tank
- o Air-to-water

Tube-in-Tube

Tube-in-tube heat exchangers are typically used on smaller systems (20 sq. ft. to 600 sq. ft. of collector area). As their name implies, they consist of a tube within a tube. One fluid moves through the innermost tube, and the other fluid moves in the opposite direction through the space between the outer and inner tubes. In many cases, two tube walls are between the fluids, affording double wall protection to the water being heated. In most double wall exchangers of this type, small passageways between the two walls provide leak detection and prevent any possibility of contamination. Some designers choose to have solar fluid in the innermost tube, and others prefer to use it for water. Be sure you know which design is used for a particular system before undertaking repairs.

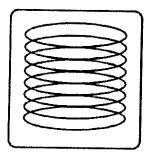
Coil-in-Tank

Another heat exchanger used for small systems is the coil-in-tank. In this type, a coil is immersed in the storage tank itself. Heated solar fluid is pumped through the coil. The tank water surrounding the coil is continually heated and rises by natural convection. Tanks fitted with heat exchangers are made with both double and single wall exchangers. Be sure to use a non-toxic solar fluid whenever the heat exchanger is single wall. Many drainback systems also use a coil-in-tank type of heat exchanger. The collector water reservoir tank may have a small coil inside it which the storage water is pumped through. In this case, the hotter fluid is outside the coil, and the cooler water to be heated is inside the coil.

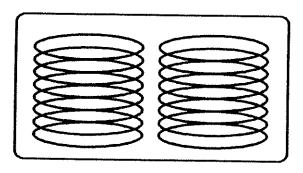
Air-to-water

Air to water type heat exchangers are usually radiator type, meaning they are configured somewhat like a regular automotive radiator. Solar transfer fluid passes thru finned coils loosing heat as air is blown across gaining heat. This type of heat exchanger is typically used for space heating, however, in some cases can be used for hot water heating. This is accomplished by using solar heated air as the heat source to the heat exchanger. As hot air passes across the heat exchanger, water is pumped from the storage tank to the heat exchanger, gaining heat, then returning to storage tank. Because of the way they are manufactured, and because of the use of two very different transfer mediums (air and liquid), air to water heat exchangers naturally are considered double wall type heat exchangers.

LIQUID TO LIQUID HEAT EXCHANGERS

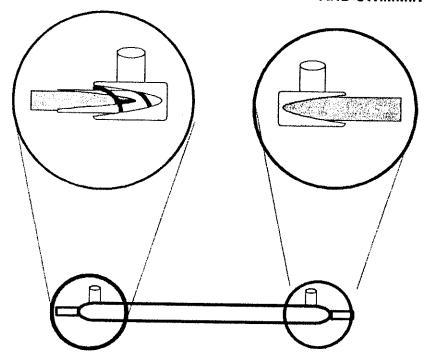


A SINGLE COIL OF TUBING IN A TANK IS A SINGLE WALL EXCHANGER



TWO COILS IN A TANK GIVES DOUBLE WALL PROTECTION BETWEEN FLUIDS IN EACH TUBE

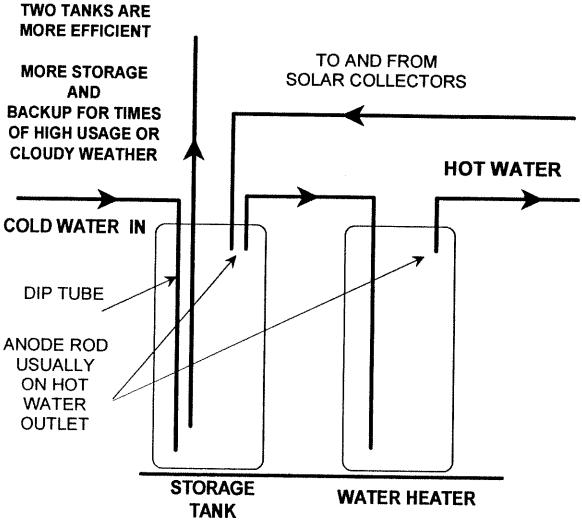
DOUBLE WALL HEAT EXCHANGERS HAVE TWO TUBES IN ONE SHELL AND ARE REQUIRED FOR POTABLE WATER SINGLE WALL HEAT
EXCHANGERS HAVE
ONE TUBE IN ONE
SHELL AND ARE USED FOR
SPACE HEAT, PROCESS HEAT
AND SWIMMING POOLS



STORAGE TANKS

The storage tank holds the water that has been heated by the collector. It is available in stock standard sizes from a few gallons to 120 gallons. Larger sizes, up to thousands of gallons, can be constructed on a custom-made basis. In many cases it is more cost-effective to use two or more "standard" tanks rather than one large "custom" one. Many manufacturers used to offer tanks with internal coils, but they are hard to find today.

Solar water heaters generally have either one or two storage tanks. Most systems have only one tank, which normally contains only an upper heating element. The element serves as a back-up heater when solar energy is not available or when hot water demand exceeds the solar heated water supply. (Some tanks contain both upper and lower heating elements.)



In a one tank system, water is forced from the lower portion of the storage tank to the collector or heat exchanger where it is heated (usually a 5-15 degree F temperature increase) and is returned to the top of the tank. A dip tube at the top or upper side of the

SOLAR REFURBISHMENT WORKSHOP SECTION 16-2

tank forces the heated water to return below the heating element, ensuring proper hot water stratification.

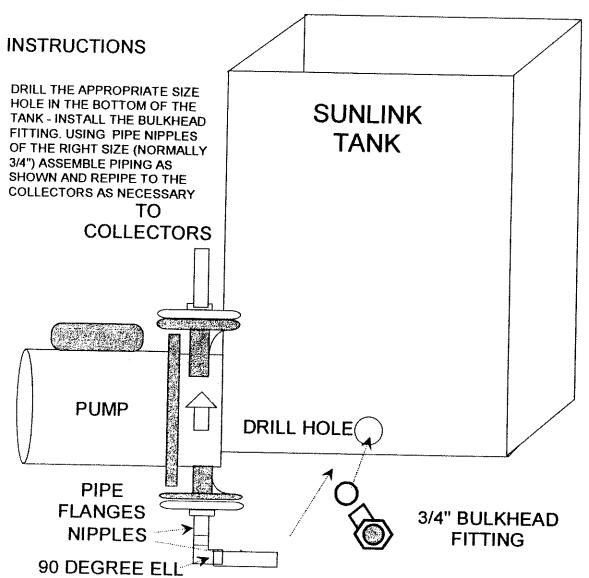
In a two tank system, one tank provides storage for solar heated water; it is plumbed directly to the solar collector or heat exchanger and does not contain a back-up heating element. This tank is plumbed to a second tank which contains a heating element or gas burner that can be used when no solar energy is available.

Except for large residential or commercial type installations, the most popular tanks are glass lined or stone lined. These tanks have an outer shell of steel that must be protected from galvanic corrosion. Some tanks use a galvanized coating. In order to provide a longer lasting coating, glass and stone linings were developed.

Since the glass lining of a tank sometimes has gaps and may be damaged during shipping and handling, an aluminum or magnesium anode rod is installed in the tank. These rods are used to protect exposed tank metal from corrosion. If two different metals are in contact with each other and water, the less "noble" of the two metals will corrode first. Once the first metal is completely eaten away, the second metal will begin to corrode.

The anode rod is sometimes called a "sacrificial anode," because it is sacrificed to protect the steel of the tank. If the anode is never allowed to completely dissolve, it will continue to protect the tank. This rod attracts corrosion and thereby "sacrifices" itself. To continuously protect the tank walls from galvanic corrosion in the presence of hard or highly conductive water, the rod should be replaced periodically. A stone lined tank does not require an anode rod since the thick stone layer provides complete coverage and is not easily broken.

TANK MODIFICATION TO REPLACE HARTELL AND LITTLE GIANT PUMPS ON DRAINBACK SYSTEMS



PIPING, INSULATION AND VALVES

Valves and Other Components

A solar heating system contains numerous other components which perform a variety of functions. These include some or all of the following:

- Shutoff valves
- Balancing valves
- Check valves
- Pressure relief valves
- Pressure and temperature relief valves
- Fill/drain valves (for solar fluids)
- Expansion tanks
- Backflow preventers
- Drain valves (for solar fluids or water)
- Air vents
- Air eliminators
- Control valves (for draindown systems)
- Vacuum breakers
- Three way diverting valves
- Tempering valves

The body materials, construction, seals and gaskets of system components must be appropriate for the solar fluid being used and the highest potential temperatures and pressures for the system.

Shutoff Valves

Shutoff valves are used to isolate other system components to allow service without requiring the complete draining of the system.

For shutoff purposes, gate valves or ball valves should be used. Globe valves, because of their high resistance to flow, should <u>never</u> be used in any part of the system.

Tanks, heat exchangers, the cold water supply, and banks of collectors are typical candidates for shutoff valves. Pumps can be isolated as well, using either separate valves or isolation flanges.

Isolation valves should not be used on solar collector arrays unless a pressure relief valve is in the piping between valves.

Balancing valves

An ideal collector array is piped so that all the collectors receive an equal flow automatically. However, sometimes it is necessary to install balancing valves in the collector piping to accomplish this. Balancing valves should be ball valves, and should be installed in the inlet line at the bottom of a group of collectors. Every group of panels should also have a thermometer or the equivalent installed in its outlet. When all the outlet piping temperatures are equal, the flows are properly balanced between collector groups.

Check Valves

Check valves allow fluid flow in only one direction. They are used in closed-loop and draindown systems to prevent heat loss at night by reverse thermosyphoning. The best choice for this application is a spring-loaded check valve. Make sure the seat and seals are appropriate for the fluid being used. It is also worth noting that tests of large numbers of check valves have found wide variations in opening pressures and high overall failure rates. For this reason, it is important to inspect check valves for proper operation at every system inspection.

Pressure Relief Valves

These valves (sometimes called PRV's) are used only in the collector loop of closed-loop systems. Since they only respond to pressure changes, they should not be used on pressurized water (city water) lines or tanks. A strong internal spring keeps the valve closed until the system pressure exceeds some preset limit. The outlet port of pressure relief valves is piped downward to within 10 in. of the floor, to protect anyone who happens to be nearby, and to minimize damage to electrical and other components, should the valve open.

Temperature and Pressure Relief Valve

Sometimes called "T and P's," these valves are similar to pressure relief valves. However, a temperature and pressure relief valve includes a temperature sensitive element at the valve inlet that extends a few inches into the hottest water at the top of the storage tank or water heater.

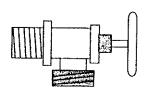
Pressure Reducing Valves

Glycol-filled loops must <u>never</u> be equipped with automatic water make-up. If glycol leaks out and is replaced by water, the system will not be protected against freezing damage.

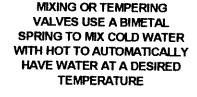
Oil-filled loops must never have water introduced to them.

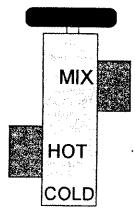
Draindown systems do not normally require a pressure reducing valve, and it is difficult to design an effective automatic water make-up system for drainback systems. Therefore, automatic water make-up is rarely used on collector loops.

COMMON VALVES AND THEIR USES



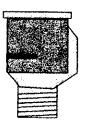
BOILER DRAIN VALVES ARE USED FOR DRAIN OR FILL APPLICATIONS

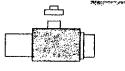




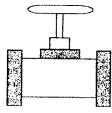
CHECK VALVES OPERATE
WITH A SWINGING GATE
OR A SPRING GATE AND
ALLOW FLOW IN ONE
DIRECTION ONLY

VACUUME BREAKERS ALLOW AIR TO ASSIST DRAINDOWN AND SOME DRAINBACK SYSTEMS TO DRAIN PROPERLY



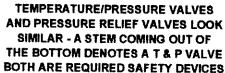


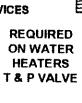
BALL VALVE

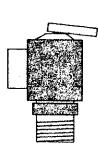


GATE VALVE

GATE VALVES AND BALL VALVES ALLOW FLUID FLOW TO BE TURNED OFF AND ON







REQUIRED ON BOILERS AND GLYCOL LOOPS PRESSURE RELIEF

Backflow Preventers

In some areas, code officials may require an approved backflow preventer in the cold water supply to the storage tank. A check valve is <u>not</u> an appropriate substitute.

The discharge port of a backflow preventer must be piped downward to avoid damaging electrical and other components, and to prevent injury to anyone in the area during blowoff.

Whenever a backflow preventer (or a check valve, despite its unacceptability) is installed, an expansion tank must be installed between the tank and the backflow preventer. If the expansion of the storage water is not accepted somewhere, the temperature and pressure relief valve on the tank will discharge heated water on an almost daily basis.

Drain Valves

Some provision for draining the liquids from all the system loops should be made. In water loops, a simple boiler drain at all low points is used. The storage tanks, particularly those in DHW systems, must be drainable for service and maintenance. In loops filled with solar fluid, the fill/drain assembly may be all that is required for complete system draining. If the piping must be routed in such a way that local low points are created, each low point should be equipped with a drain.

Boiler drains may not be acceptable for this purpose, because their seats and packings may not be compatible with the solar fluid. The simplest way to provide an inexpensive drain is the use of an all-metal "coin vent." These manual air vents have no plastic or rubber seals and are relatively inexpensive. If the low spot is at an elbow, a baseboard tee can be used instead of an elbow. These tees include an 1/8" female threaded port designed for the coin vents. Whenever a drain is being used, air must be introduced into the top of the loop to speed up the draining process. The following section on air vents provides some information on this.

Air Vents

Automatic (float type) air vents are probably the most incorrectly applied component in solar systems. Very few, if any automatic air vents are capable of withstanding the pressures, temperatures, solar fluids and other conditions they are exposed to in solar applications.

Automatic air vents can be used <u>only</u> in piping loops containing water. If used with solar fluids, an automatic air vent would eventually vent enough fluid vapor or leak enough to render the system inoperative. Automatic air vents shall not be installed in piping loops containing solar fluid.

SOLAR REFURBISHMENT WORKSHOP SECTION 17-5

The high points of closed-loop systems containing solar fluids must be vented, but with manual (coin) vents. The vent should be a simple needle valve, with absolutely no plastic seals, seats, wafers, or other non-metal components. During installation and maintenance procedures, service personnel can open the valve to check for air or to let it out. Otherwise, the vent stays closed. The high points of draindown and drainback collector loops, and the high point of storage water loops should use a high-pressure automatic air vent. The vent must be rated for at least 125 PSI, although 150 PSI is better.

The cap on automatic air vent is used to prevent the entry of dust which would clog the mechanism, so it is never fully tightened. The air vent should be constructed of metal. Plastic air vents are not recommended because catastrophic failure is common.

Air Eliminators

Air eliminators, also called air scoops, are normally used only on the collector loops of large closed-loop systems. Their internal construction includes vanes to push entrained air bubbles upward to a holding chamber. When enough bubbles have been collected, an automatic air vent at the top of the unit vents the air.

The air vent should allow flow only during startup operations. They must be closed during normal operation, after all the air has been removed from the system. Again, be sure the vent is capable of withstanding the solar fluid itself, and the system pressures.

Most air eliminators feature a threaded port on the bottom for the system expansion tank. This is acceptable, but it means the eliminator/vent/expansion tank package must be installed on the suction side of the solar pump.

Collector Loop Control Valves for Draindown Systems

Draindown systems can be emptied and filled by a single control valve, or a group of three individual solenoid valves. In either approach the system control operates the valve package, draining the collectors and exposed piping during times of freezing temperatures, and refilling it during warmer periods.

Larger systems use two normally closed solenoid valves and one normally open one. When outdoor temperatures are above freezing the two normally closed valves are open, allowing water from the tank to fill the collector loop. The normally open valve in the drain line is closed, keeping water in the system.

To drain the collectors and exposed piping, the power to all three valves is turned off. Normally closed valves keep water out of the collectors. The normally open valve allows water to drain from the collectors. This water is not recovered, and is piped to a drain. The system is considered "fail-safe," because under normal failure modes, such as a power failure, the system will drain, thus failing in a safe state.

SOLAR REFURBISHMENT WORKSHOP SECTION 17-6

Standard solenoid valves are typically used in this type of system. For adequate flow, a minimum of 1/2 inch or 3/4 inch ports are required. The solenoids are usually 120 volts, and wetted materials are normally brass or stainless steel.

Vacuum Breakers

A vacuum breaker remains closed only as long as the system it is piped into has pressure. When the system pressure falls below atmospheric pressure, it opens. Vacuum breakers are used at the top of draindown and drainback systems to allow air to enter the loop to facilitate rapid drainage. They are sometimes installed above the cold water inlet of storage tanks and water heaters to eliminate vacuum conditions that could collapse the tanks. As is the case with automatic air vents, no vacuum breaker manufacturer endorses the use of their product outside.

Three-Way Diverting Valves

Some space heating applications, particularly those involving hydronic back-up, use motorized three way valves for automatic control of the distribution of solar heat. The valve must be rated for the water pressure and temperatures expected in the system, but these are not normally a problem. Manual three-way valves are sometimes used to isolate or bypass the storage or back-up heaters in DHW systems. Because slight amounts of leakage are typical, they cannot be used as shutoff valves for service purposes. However, as an isolation or bypass valve, they are more convenient than a pair of two-way valves.

Tempering Valves

Tempering valves are an additional safety feature that most solar water heating systems should have installed. The valves primary function is to mix cold water to the solar heated hot water preventing the possibility of scald injuries should the water in storage be excessively hot.

Pipe and Tank Insulation

The most efficient solar heating system cannot deliver heat it has lost from piping and tanks. System insulation must be thermally adequate, continuous and durable. Regular inspection and maintenance is necessary to ensure the insulation and jacketing have not been damaged.

Pipe Insulation

At a minimum, all solar piping under 1 inch size (nominal) should be insulated to R-4. All piping 1 inch or larger should be insulated to at least R-6. Exterior piping of all sizes benefits from insulation to R-7.

Protection from moisture and ultraviolet radiation is necessary for all exterior insulation.

Polystyrene or polyethylene should *never* be used for solar applications. These materials melt at a temperature of 165 degrees F, well below the expected temperature for piping in most parts of all systems.

GOOD INSULATION PRACTICES REQUIRE THE FOLLOWING:

- All exterior joints must be sealed and protected, including those between the insulation and collectors, and roof penetrations.
- Pipes must be supported on the outside of the insulation, using saddles to distribute the piping weight without crushing the insulation.
- Pipe supports must allow piping and insulation to move during periods of thermal expansion and contraction without tearing the insulation.

Material R-value (per in.) Fiber glass 4.0		Trade Name(s)	Must be protected from moisture, joints are difficult to fabricate, Max. temp. is 300°F		
		Certain Teed			
Closed cell flexible elastomeric foam	3.5	Armaflex Rubatex Halstead	May require two layers, does not need moisture protection, must have UV protection, max. temp. is 220°F		
Closed cell rigid protection,	6.5 to	Solar-7 Insultek	Must have UV and moisture		
urethane and poly- isocyanurate foams	7.0	Insulsleeve	max. temp. is 250°F		
Open cell Polystyrene Polyethylene		Samon's Hardware stores	Melt at low temperatures		

SOLAR REFURBISHMENT WORKSHOP SECTION 17-8

Gauges Measurements of two properties are usually necessary; temperature and pressure. Other things can be measured or monitored, but these two are the most critical.

Temperature

Temperatures in solar systems are measured in one of three ways:

- o Fixed thermometers
- o PT plugs or thermometer wells (with movable thermometers)
- o Electronic sensors (usually thermistors)

Price and accessibility are the usual criteria for deciding which approach to use at a particular system point. All are sufficiently accurate for normal purposes.

Measuring collector feed and return line temperatures allows service personnel to confirm solar loop flow, and to get a rough idea of system performance.

In systems with a pumped storage loop between a heat exchanger and the storage tank, two more temperature measurement points may be appropriate. At a minimum, the storage tank outlet should be equipped with a way to measure temperature. This allows service personnel to confirm that energy has been transferred into storage, and is being used.

Other candidates for temperature measurement include the feed and return of the auxiliary systems, the feed and return of space heating distribution loops, and the points measured by differential thermostat sensors.

Pressure

Pressure measurement is necessary in the collector loop of closed-loop systems. It is the only practical way to confirm that there is adequate solar fluid for proper operation.

Measuring the pressure on each side of a pump makes it possible to determine the flow rate through the pump.

Differential pressure measurements can also describe flow rates through heat exchangers, collectors or other components, if the manufacturer can supply flow rate vs. pressure drop information.

Specialized flow setting devices use a restriction of known characteristics with pressure measurement ports on each side. A differential pressure gauge is normally used to determine and help set the flow rate.

Occasionally, a draindown system will have a pressure gauge in the drained portion of the collector loop. On cold nights, one look at the gauge tells whether or not the water has drained.

Pipe Insulation Degradation

Ultraviolet (UV) rays and extreme system temperatures accelerate degradation of many materials, especially exterior pipe insulation. Although many manufacturers claim that their pipe insulation contains ultraviolet inhibitors and does not require a protective coating, sustained exposure appears to degrade almost every unprotected material.

Therefore, all insulation should be inspected for degradation and be replaced as necessary. Exterior insulation should be coated with UV resistant material. Several insulation manufacturers offer a coating for this purpose. Latex paint which matches the roof color and has pigments which inhibit UV degradation is also available.

Insulation that has degraded due to high temperatures must be replaced with a brand that can withstand such temperatures. This is critical for insulation that is used on the collector return line directly adjacent to the collector. When replacing exterior insulation on the roof area valves, take care not to restrict operational parts of these valves.

Piping and Ductwork

The tube material of the circulation system must be compatible with the transfer fluid. The use of dissimilar metals, as discussed earlier, should be avoided to eliminate the possibility of galvanic corrosion. The preferred choice for SDHW system plumbing is copper tubing. However, if cost is a factor, using the less expensive aluminum or steel absorber tubing in the collector or piping runs with corrosion inhibitors and buffers is an alternative. With all metal plumbing, glycol-based antifreeze solutions must be checked periodically and the pH prevented from becoming acidic.

If there are multi-metal connections, there will be problems with galvanic corrosion. Aluminum is the most susceptible to corrosion and requires extra protection. Copper to copper fittings are generally the least corrosive, but the most expensive. Copper fittings connected to steel tanks should be joined by a brass or bronze nipple.

Aluminium and steel tubing have more pronounced problems with scaling than copper.

PVC plastic pipe should not be used for hot water applications. However, CPVC can be used at temperatures up to 180° F., though sagging may occur about 160° F., and extra support should be included. Sagging pipes make complete draindown or system flushing difficult.

Interior pipe runs should be insulated with a minimum of R-4 while exterior pipe should be at least R-8.

FLUIDS, AND FLUID COMPATIBILITY

<u>Solar Fluids</u> The best fluid available for moving the heat from solar collectors is water. Unfortunately, when water is exposed to freezing temperatures it becomes solid and expands, two undesirable characteristics.

Special non-freezing fluids have been developed for solar applications. The three types typically used are:

- o Glycol/water mixtures
- o Synthetic oils
- o Silicone oils

These materials have different characteristics, but they all have one thing in common, their specific heat and thermal conductivities are lower than water. This results in higher pump and heat exchanger requirements and costs.

CAUTION: Fluids should always be replaced with the same fluid if possible. You should never replace propylene glycol with ethylene glycol (car antifreeze) unless you are sure the system has a double wall heat exchanger.

Glycols

Glycols are either ethylene glycol or propylene glycol usually in a 50/50 mixture with distilled or demineralized water. Special inhibitors are added to help prevent the fluid from becoming corrosive.

Propylene glycol is classified as non-toxic, while ethylene glycol is toxic. This difference is critical to occupant safety. Generally, a toxic solar fluid should only be used whenever the heat exchanger is of double wall construction. If a single wall exchanger is used, a non-toxic fluid should be used. This is particularly important when the storage fluid is potable water, as with a DHW system.

Toxic fluids should also be stored and handled carefully. Access by children and pets should be avoided.

Because the glycols eventually break down chemically, annual testing is required.

Piping systems to be filled with glycol mixtures can be pressure tested and flushed with water before the glycol/water mixture is put in the system. It is important to remove "hung-up" water during the filling process to avoid diluting the fluid.

Pump gaskets and seals, expansion tank diaphragms, valve seals and seats and other elastomers and plastics must be compatible with glycols. Typical acceptable materials are EPDM, Hydrin, Viton and Teflon. Thread sealants must be Teflon based.

SOLAR REFURBISHMENT WORKSHOP SECTION 18-2

Glycol/water mixtures have a lower surface tension than water. This results in a "leakier" fluid, making tight joints more important than usual.

Glycol-based fluids should be checked for glycol concentration and the condition of the corrosion inhibitor. If these two cannot be checked, at least check the pH (acidity/alkalinity) of the fluid.

To check glycol concentration, some manufacturers (including Dow Chemical Company) furnish simple test kits with simple test strips and color charts. Another method is an optical refractometer. Both these methods require only a few drops of fluid and are quite simple.

To check the condition of the corrosion inhibitor, measure either the pH or the reserve alkalinity of the fluid. Most glycol manufacturers recommend that the pH should not drop below 6.0 and the reserve alkalinity should not drop below 8.0. Should either condition be too low, the fluid must be replaced or reinhibited.

To check the pH, use pH paper or tape, or have a laboratory analyze the fluid. If using pH tape, use fairly fresh tape with a pH range from 6.0 to 8.0. Water treatment specialists or swimming pool chemical suppliers are good sources for pH tape.

To check the reserve alkalinity, use a special test strip from the manufacturer, or have a lab check it. Some glycol manufacturers offer free testing for systems using large amounts of fluid (over 50 to 200 gallons).

The color of most glycol-based solar fluids is not usually a good indicator of fluid condition. However, if the fluid appears and smells "burnt," or has visible sludge, it should be replaced after the system is flushed out.

Synthetic Oils

The major advantage of synthetic oils is their almost unlimited lifespan. Furthermore, unless the fluid leaks out of the piping system, virtually no maintenance is required. Toxicity is low as well.

The specific heat and thermal conductivity of synthetic oils is considerably lower than water. These factors increase pumping and heat exchanger requirements and costs. Synthetic oils attack more materials than the glycols, and can damage roofing materials if spilled. Materials resistant to degradation include Teflon, Viton and Hydrin.

The surface tension of synthetic oils is very low, resulting in a fluid which is even more difficult to confine in piping.

Synthetic oils must <u>never</u> be mixed with water, and must be introduced into a perfectly dry piping system. Water must never be used for pressure testing or flushing.

SOLAR REFURBISHMENT WORKSHOP SECTION 18-3

Oils do not require replacement or reinhibiting. However, the fluid pressure must be adequate.

Silicone Oils

Silicones have many of the characteristics of synthetic oils. Differences include an even lower surface tension, so they are even harder to confine. Thread sealants must be fluorosilicone-based, or joint failure is inevitable. Silicone oil is very expensive, typically 3 to 10 times the cost of other fluids.

Silicone oils must never be mixed with water, and must always be introduced into clean, dry piping systems. Water must never be used for pressure testing or flushing.

Oils do not require replacement or reinhibiting. However, the fluid pressure must be adequate.

<u>Solar Fluids</u> Solar loops will work only if they have adequate fluid in them. Drainback reservoir tanks must be filled to the correct level. Closed-loop systems must have adequate pressure.

Check for the recommended liquid level or pressure from the system's operation and maintenance manual.

Water

Draindown systems use city or well water in the collector loop. If water quality is poor, water treatment equipment may be used. The product water from the treatment equipment should be checked.

Usually, water is "softened' to remove scale-causing "hardness." Typically, this is done with ion-exchange softening equipment. Test for hardness with any standard water hardness test equipment.

Sometimes iron creates problems by building up on the inside of piping systems and reducing flow rates, and by giving the water a poor appearance and taste. Standard ion-exchange softeners, specialized iron filters or chlorine-based treatments are used to remove iron. These can all be easily checked with a test kit for total iron (both ferrous and ferric iron).

Drainback systems normally use distilled or deionized water.

EXPANSION TANKS

Expansion Tanks

Expansion tanks are normally used in the collector loop of closed-loop systems. Occasionally they are found in the cold water supply to storage tanks, but only if a backflow preventer check valve is also in that line.

Because fluids are not compressible, expansion tanks are needed to maintain a fairly stable system pressure. Without one, a closed piping system undergoing temperature changes would fluctuate from zero pounds to many hundreds of pounds of pressure.

Expansion tanks for solar fluids are normally constructed of raw or galvanized steel. Some have a flexible internal diaphragm maintaining a separate air cushion. Diaphragm-type tanks are preferred for solar applications. The air side of the tank usually has a Schrader valve (similar to the ones used on automobile tires) to allow checking and changing the air pressure. The air cushion normally comes pre-charged from the factory at 12 PSI.

The standard diaphragms used on expansion tanks for the traditional hydronic applications are neoprene. These are quickly destroyed by all non-freezing solar fluids currently in use. Glycols should use an EPDM or Hydrin diaphragm, and both types of oils must use one made of Hydrin or Viton. Galvanized tanks should never be used with glycols.

Expansion tank sizing, combined with calculations of the appropriate system fill pressure, are very important with closed-loop systems. Undersized tanks or incorrect fill pressures usually result in a loss of system fluid, followed by other negative consequences.

Determine the Number and Size of Expansion Tanks

The fill pressure table below is based on expansion tanks manufactured by Amtrol, Inc. If Amtrol tanks are not used on the solar system, ask the design authority for assistance in determining the "Amtrol equivalent" of the existing expansion tank or tanks.

In the table shown, 1x15 refers to a single #15 Extrol tank, 1x30 refers to a single #30 tank, 15+30 means a #15 and a #30, and 2x15 means two #15 tanks. Other listings follow the same pattern.

Determine the System Fluid Temperature During Filling

Use a thermometer in the charging bucket to measure the temperature of the fluid while you are charging the system. The fill pressure chart adjusts the final fill pressure based on the fluid temperature.

Determine the System's Elevation Above Sea Level

It is necessary to make an adjustment to both the expansion tank air pressure and the recommended system fluid pressure for the site's elevation above sea level.

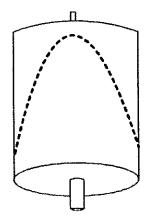
Fluid Pressure for Closed Loops								
Extrol Tank(s)	Max. System	Fluid Pressure, PSI at Fluid Temperatures of:						
Model #	Volume	40°F	60°F	80°F	100°F	120°F	140°F	160°F
(Gal.)								
1 x15	4.7	32	33	34	35	36	37	38
2x15	9.4	32	33	34	35	36	37	38
1 x30	12.5	33	34	35	36	37	39	40
15+30	17.2	33	34	35	36	37	38	40
2x30	25.0	33	34	35	36	37	39	40
1 x90	44.5	33	34	36	37	38	40	42
30+90	56.0	33	34	35	37	38	39	41
2x90	88.0	33	34	36	37	38	40	41
3x90	132.0	33	34	36	37	38	40	41

Note: This chart is based upon sea level pressure. Add one-half pound to the fill pressure and expansion tank air pressure for every 1000 feet the system is above sea level.

In all cases, the expansion tank air pressure, measured with no fluid pressure, is 30 PSI at sea level. Add one-half PSI to the listed air pressure and system fill pressure for every 1000 feet the system is above sea level.

EXPANSION TANKS

CYLINDER TANKS CAN BE USED
IF THE FLUID LEVEL IS ALWAYS
ABOVE THE INLET AND OUTLET
TO PREVENT AIR FROM ENTERING
THE SYSTEM



IF BLADDER TYPE
TANKS ARE INSTALLED
UPRIGHT THEY WILL
STILL ALLOW FOR
EXPANSION IF THE
BLADDER FAILS

FLUSHING AND FILLING GLYCOL SYSTEMS

Fill/Drain Valves

These valves are used for introducing or removing non-freezing solar fluid from the collector loop of closed-loop systems. Simple boiler drains can be used, if their seats and packings are compatible with the solar fluid. In other cases, a shutoff valve and a hose adapter perform the same function without compatibility problems. Finally, specialized poppet valves have been used by different manufacturers for this purpose.

The fill/drain assembly includes the two valves on each side of a shutoff valve or check valve. As solar fluid is pumped into the system, the center valve forces the fluid to move up through the collectors, and back out the other side of the assembly. Since the fluid goes back into the bucket it was originally pulled from, it moves around and around the system, forcing out the air. After charging, the fill/drain valves are closed. If children have access to the system, caps are normally provided to reduce the chance of tampering.

This process ensures a completely filled system, but it <u>does</u> require an independent pump for charging the system.

Draining and Flushing Glycol and Drainback System Collector Loops

ldeally, a drain port is in place at the lowest point of the system. Open and drain the used glycol or water.

Small amounts of glycol trapped in low points of the loop that are in the flow can be left undrained. However, fluid in "dead legs," such as expansion tanks, must be drained out. This may require cutting into the piping or unthreading joints, but it must be done to avoid contaminating the new fluid.

Install drain plugs as you repair the piping. Use teflon-based thread sealants.

Dispose of used glycol properly, according to local requirements. Consider reusing non-toxic glycol (propylene glycol) for less critical applications, such as freeze protection for drain traps.

If a fill/drain assembly is not part of the system, install one. It can be placed in any part of the loop which contains the flow of all the fluid, but an ideal spot is between the system low point and the return line coming from the collectors.

Normally a check valve is used, a gate or ball valve can be used instead, but only if a working check valve is somewhere else in the loop. Having two check valves in the loop is acceptable, since one can back up the other.

SOLAR REFURBISHMENT WORKSHOP SECTION 20-2

Make sure the seals and seat of the valves used are compatible with the glycol. Use a teflon-based thread sealant.

Hook up a hose to a cold water line, and connect this to the "fill" fitting downstream of the check valve. The arrow on the check valve will point to this fitting. Connect another hose to the "drain" fitting, and run it over to a suitable drain. Use approved methods to collect and dispose of used glycol solution.

Normally city pressure has adequate flow and pressure to flush out the system. Occasionally, a booster pump is needed in the "fill" line, to push the water to the top of the system. If possible, flush the loop on a cloudy day to avoid thermal shock of the collectors.

Flush the system with city water until the fluid coming from the "drain" fitting is clear. Make sure the water is moving through all parts of the loop. On a sunny day, all the collectors should be at the same (fairly cool) temperature.

Turn off the water, disconnect the fill hose, and allow the system to drain. Drain out any "dead legs." Small amounts of "hung-up" water in the loop can be flushed out during recharging. Dispose of used glycol properly, according to local regulations.

Refilling (Recharging) Glycol or Oil Loops

Before recharging the system, make sure the expansion tank capacity is adequate for the system and fluid. This is especially important if the system has a history of relief valve blow-off.

It may be necessary to adjust the air pressure of diaphragm-type expansion tanks <u>before filling the system</u>. Before introducing a new fluid, pressure test the piping system with compressed air. Use air rather than water to prevent damage to pipe insulation or building components if leaks appear. Also, <u>water must never be introduced into an oil loop.</u>

If possible, test at 75 PSI for a period of two to three hours. If pressure relief valves or other components cannot withstand this pressure, isolate them or remove them from the system. A lower test pressure can be used for a longer period of time, but it is not as good a test.

During the test, the pressure will fluctuate slightly (5 to 10 PSI) as the system heats up and cools down. Leaks can be found by spraying or brushing a liquid soap and water solution on joints and looking for bubbles. Commercial leak detection fluids can be used instead.

If there is any doubt about the system leaking, continue the test overnight.

After the test is complete, let the air out of the system. To charge the system, connect up a charging system as shown on the next page. The charging pump should be a shallow well jet pump, or a jet pump with a shallow well adapter capable of developing at least 50 PSI in a deadhead (no flow) situation. A filter or strainer should be between the bucket and the charging pump inlet. Change the filter after every five systems.

Following the diagram, one hose will run from the bucket or drum to the <u>inlet</u> of the charging pump, going through a filter or strainer somewhere along the way. Another runs from the <u>outlet</u> of the charging pump to the <u>fill</u> port of the fill/drain assembly. This is the downstream port that the check valve arrow points to. The final hose is connected to the drain port, and leads back to the bucket.

For some systems, especially prepackaged DHW systems, special fittings will be required for fill/drain assembly connections. If replacement of special fittings is necessary, replace with fittings compatible with transfer fluid to be used. Most all other systems come standard with fill/drain fittings with male hose thread ends. Washing machine hoses attach readily to these types of threaded ends.

The fluid in the bucket is pulled through the charging pump and into the system. The check valve forces the fluid to move up the feed line to the collectors, up through the collectors, back down the return line and back into the bucket (The same way boiler/baseboard loops are initially filled).

If a gate ball valve is used instead of a check valve, it must be closed during the charging process.

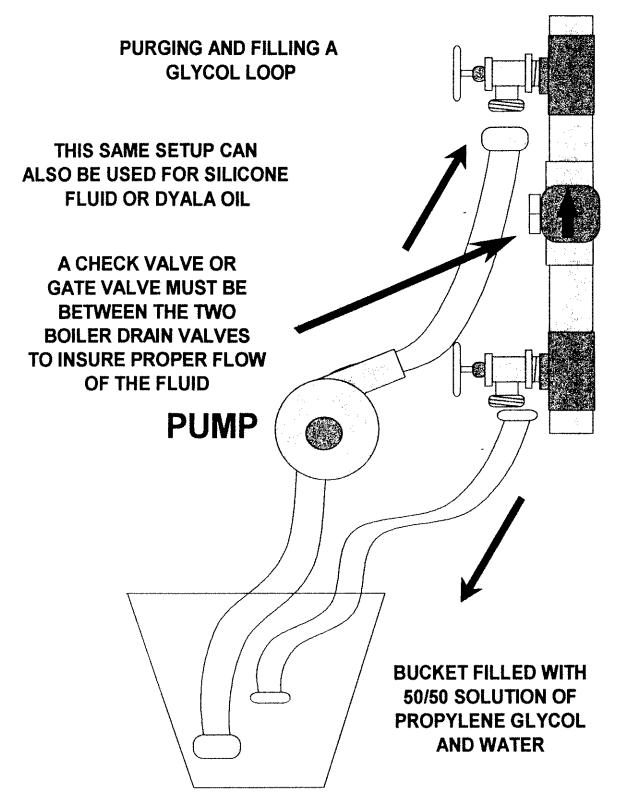
The drain port hose is submerged in the fluid to make it easy to see any air bubbles coming out of the system. This is similar to the process of bleeding automobile brakes.

Pour enough fluid into the bucket to fill it to within about two inches from the top of the bucket. Make sure all vents are closed, and turn on the charging pump. Very quickly, air will come out the drain hose. If the air is coming out too violently and fluid is being blown out of the bucket, hold the hose above the fluid until liquid starts to come out of it.

CAUTION!

The fluid coming out the discharge hose can be <u>extremely hot!</u> Use insulated gloves to hold the hose or <u>clamp it securely</u> to the side of the bucket. Use of eye protection is recommended.

If water was used to flush the system, the first fluid to come out of the system is mostly water. Discard this "hung up" water in a separate bucket, then move the discharge hose back to the "good" fluid bucket.



As the pump pulls fluid out of the bucket, keep pouring more in. Keep the bucket at least half full at all times.

SOLAR REFURBISHMENT WORKSHOP SECTION 20-5

If the fluid level never drops, the charging pump needs priming, or is faulty. If the fluid level drops for a while, then stops, and no fluid is coming out of the discharge hose, the pump is not strong enough to push fluid to the top of the collectors. It is a good idea to turn the solar control to the "On" position while charging, to help the process and purge air from the pump.

After the system has been completely filled, and all the air has been purged, no additional bubbles will be seen. Run the charging system for at least another ten minutes. The fluid should be completely free of surface bubbles, and have no sign of milkiness. A few extra minutes spent can save a return trip to recharge the system again.

Close the drain fitting, and allow the charging pump to build to the desired system pressure. Once the pressure is reached, close off the fill valve, and turn off the charging pump. Leave the pump and hoses connected.

Turn off the system control if it was turned on. Open the gate or ball valve, if one was used in the fill/drain assembly.

After filling a glycol loop, test a small sample of the fluid. Note the pH, glycol percentage and reserve alkalinity in the operation and maintenance record for that system.

After the system has been off for about ten minutes, <u>briefly</u> open the air vent on each array of collectors. A small amount of air may be present. If more than a brief hiss of air comes out, charge the system for at least ten minutes more and check the vents again.

If the charging process seems to be going well, but air still shows up in the system, check the suction hose and fittings on the charging pump for leaks. A jet pump can suck in air and still pump fluid.

Drain enough fluid to drop the system pressure down to the recommended pressure. Be sure to add one-half PSI for every 1000 feet of altitude above sea level.

It may be desirable to use the charging pump to return fluid from the bucket into the original container. Disconnect and drain the hoses.

FLUID CAPACITIES

Material or Equipment	гина Сараспу					
Typical 3' by 8' or 4' by 6' collector	3/4 to 1 gallon					
Typical 4' by 8' collector	l to 1 1/4 gallons					
Typical 4' by 10' collector	1 1/4 to 1 1/2 gallons					
1/2" copper tubing (per foot)	0.012 gallons					
3/4" copper tubing (per foot)	0.025 gallons					
1" copper tubing (per foot)	0.042 gallons					
1 1/4" copper tubing (per foot)	0.065 gallons					
1 1/2" copper tubing (per foot)	0.093 gallons					
2" copper tubing (per foot)	0.161 gallons					
15' coil-in-tank heat exchanger, 3/4"	Approx4 gallons					
20' coil-in-tank heat exchanger, 3/4"	Approx5 gallons					

HARD WATER PROBLEMS AND SOLUTIONS

Descaling

Water with a high dissolved mineral content, "hard" water, will deposit scale on heated surfaces. This usually occurs in loops filled with "city" or well water, such as DHW systems. The water passageways of heat exchangers are very suceptable to hard water conditions, and eventually require descaling.

Some heat exchangers can be mechanically descaled with brushes. This process requires draining and opening the heat exchanger and running the brush through each tube several times. After brushing, flush the heat exchanger with plenty of water to avoid allowing small pieces of scale to get stuck in system components.

In many cases, the scale cannot be removed mechanically. The heat exchanger may not be built for it, or the scale deposits may be too hard or thick. In these cases, chemical descaling, using various types of acid is necessary.

A very effective yet non- toxic, readily available acid is white vinegar, try this first, if results are not satisfactory proceed with the following.

CAUTION!

If the water being heated is <u>potable</u> (used for drinking, cooking or bathing), <u>the descaling solution should not be toxic!</u> If this is not possible, be sure to completely flush the heat exchanger with fresh water after descaling.

One acceptable descaling solution is phosphoric acid, sold by Stewart Hall as "ScalestripTM." Another choice is Intech 52TM, which is shipped as a dry powder, and is mixed with water just before use.

Isolate and drain the water side of the heat exchanger. Turn off the solar control, to prevent the circulation of hot solar fluid.

Connect two hoses to the water inlet and outlet of the heat exchanger. Connect one hose to the outlet of a small acid pump. (Little Giant Model 2E-NVDR is appropriate.) Connect a third hose to the inlet of the acid pump.

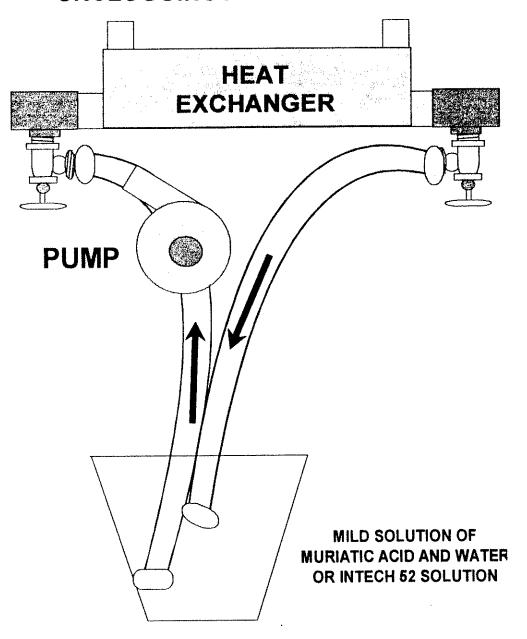
Follow the manufacturer's instructions to mix the descaling acid with water. Generally, solutions should be a maximum of 7% by volume. Make enough to fill the water passageways and still have at least two inches left in the bottom of a bucket.

Drop the two unused hose ends below the surface of the acid. Turn on the pump, and allow the dilute acid to circulate through the heat exchanger for 15 to 30 minutes. The time interval depends on the severity of scaling.

Turn off the pump, and allow the acid to drain out of the heat exchanger as much as possible. Hold up the acid pump to allow it and the hoses to drain. Disconnect the pump from the hose leading into the heat exchanger.

Dispose of the used acid properly. If it is vinegar, or phosphoric acid, such as Scalestrip, it is biodegradable and can be flushed down a toilet. Reflush the toilet several times to

UNCLOGGING A HEAT EXCHANGER



SOLAR REFURBISHMENT WORKSHOP SECTION 21-3

clear the acid from traps. If the acid is not biodegradable, dispose of it in accordance with local requirements.

Connect the heat exchanger inlet hose to the fresh water supply. Flush the heat exchanger for at least five minutes. Once every trace of acid has been purged out, disconnect the hoses. Repipe the heat exchanger, and purge the air from it.

Rinse out both the acid bucket and hoses. Pump fresh water though the acid pump briefly and drain it before returning it to storage. Dispose of the used acid-water mixture in accordance with local requirements.

Water Corrosiveness

Water can be corrosive for a number of reasons. The three most common causes are:

- o low pH (acid water)
- o high dissolved oxygen content
- o high dissolved solids content

Cutting a small section of piping from an easily drained, easily repaired section of piping is sometimes the best way to determine if the water is corrosive. Knowledge of local conditions is a traditional way to know that aggressive water is causing a problem. Laboratory analysis is another choice, especially when it is difficult to determine what is causing the water to be corrosive.

Water Hardness- Scaling

Water with a high percentage of calcium and magnesium compounds is usually described as "hard." These minerals will deposit on piping system surfaces, particularly heated ones. The reduction in piping diameter will cause flow rates and heat transfer to drop.

If the system flow rates at the time of installation are known, a gradual reduction usually indicates that scaling is occurring. It may be possible to visually inspect heat exchanger passages. In extreme cases valves will not seat properly, and pumps may be damaged by the build-up.

Water With Iron or Manganese

Iron and manganese usually do not greatly affect solar systems, except for their contribution to the water's corrosivity. In extreme cases, ferric iron build-up in piping systems may cause problems similar to hardness.

Water treatment professionals are equipped to test for and treat all of these problems. In severe cases, bringing in a specialist should be considered.

CALCULATING BTU OUTPUT/SIZING INFO

Performance

Solar hot water heaters are normally sized to supply about 60% of your annual hot water needs. Actual performance will vary according to weather conditions, system design and installation. During the winter, performance is usually 25% of the water heating load, while summertime performance averages approximately 80%. Although solar heated water can be stored, the system produces hot water only during the day. Ideally, hot water demand should be tailored to times when the sun is shining and after the storage tank is heated. A good rule of thumb for tank storage capacity is 2 gallons of storage for 1 sq. ft. of collector surface area.

RULES OF THUMB

FOR ROUGH APPROXIMATIONS ONLY

ONE BTU IS APPROXIMATELY EQUAL TO THE ENERGY IN A COMMON MATCH

DEFINITION: BTU = AMOUNT OF ENERGY NECESSARY TO RAISE 1 LB. OF WATER (A PINT) ONE DEGREE F.



A ROUGH ESTIMATE OF THERMAL ENERGY PRODUCED BY A FLAT PLATE COLLECTOR

SQUARE 800 to 1000 FOOT OF BTU / DAY ON SOLAR COLLECTOR A SUNNY DAY 600 to 800 SQUARE **FOOT** BTU / DAY ON OF SOLAR COLLECTOR A PARTIALLY **CLOUDY DAY** SQUARE 400 to 600 FOOT BTU / DAY ON SOLAR COLLECTOR A CLOUDY DAY It is helpful to know your family's hot water consumption rate. An estimated average is 20-25 gallons of hot water per person each day, but this figure varies depending on the number and size of your hot water consuming appliances.

Collector Efficiency

Depending upon the environment a flat plate collector is placed in (climate, location, ect.), most will produce 400 to 1000 BTU's per square foot of absorber surface area per day (see rule of thumb). For example, a 4 foot by 8 foot flat plate solar collector has a total surface or absorber area of 32 square feet. If the collector is producing 1000 BTU's / sq. ft. / day the total amount of energy produced would be $32 \times 1000 = 32,000$ BTU's per day. That amounts to just under a million BTU's per month, and around 12 million BTU's per year.

What is 12 million BTU 's per year worth? Well, to convert BTU's to the energy required to heat water we will need to know what type of energy is currently in use and how much it costs. For example, if converting BTU's to electricity, 1 BTU is equivalent to .29287 of a watt. 12 million BTU's x .29287 = 3,514,440 watts or approximately 3,514 kw's.

If the price of electricity is 10 cents per kilowatt, 3,514 kw's represents a savings of approximately \$351.00 per year.

System Efficiency

Evaluation of the performance of an entire SDHW system over a long period is a complex problem. Factors such as storage size and type, nature and timing of load, and system controls come into play. For these reasons specialized computer programs (f-chart, TRNSYS,SOLCOST) have been developed. Your dealer may be able to provide an analysis for your particular system.

以外,我们就是一个人,一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们也会会一个人,一个人,我们就是一个人,我们就是 一个人,一个人,一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是一个人,我们就是

Reliability

Systems should last 15-20 years, although it is probable that some components will need repair or replacement within that time. In liquid systems, widespread corrosion and damage from freezing in open loop systems, or damage to collectors from extreme and frequent temperature fluctuations should be considered.

The primary factor in system reliability is the quality of the installation. Selection of qualified contractors experienced with solar heating applications is very important.

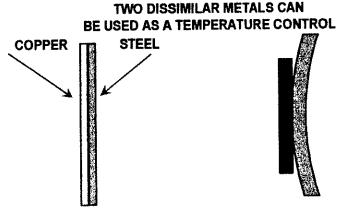
BASIC SETPOINT CONTROLS

Basic controls mainly consist of simple switches to turn equipment on and off. A common light switch is called a manual switch since you have to turn it on and off. Automatic controls are actuated by light, temperature, time and many other things. Solar controls are usually actuated by temperature. The most common temperature sensitive switch is a simple room thermostat. Room thermostats and switches like them are called setpoint controls since they are actuated at a single "set point". These controls are most frequently of a type called bi-metal. A bi-metal switch is made of two different metals and bends

when temperature changes. The bending bimetal can be manufactured into a switch to turn on and off with temperature changes.

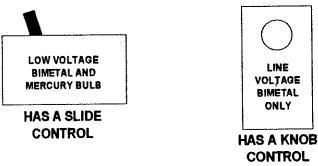
Another common setpoint control is bulb. Many remote commercial and industrial controls are remote bulbs. Setpoint controls that are completely electronic are becoming more common today, but most are still overwhelmingly bimetals. Electronic controls are used in more complicated systems such differential temperatures, and light and time sensing devices.

Many controls use a relay to control one higher voltage with a lower voltage. Relays are electro-mechanical devices.



BECAUSE OF A DIFFERENCE OF EXPANSION AND CONTRACTION BETWEEN THE TWO METALS, A CHANGE IN TEMPERATURE WILL CAUSE THE "BIMETAL" TO BEND AND ALLOW CONTACT FOR ELECTRICAL CURRENT TO FLOW

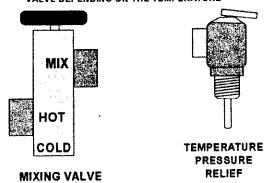
ALMOST ALL COMMON THERMOSTATS IN USE TODAY
USE A BIMETAL AND/OR A MERCURY BULB



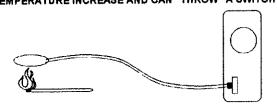
SINCE MERCURY IS A GOOD CONDUCTING METAL
THAT IS ALSO A LIQUID, IT CAN BE USED AS A
RELIABLE QUIET ACTING SWITCH

SOLAR REFURBISHMENT WORKSHOP SECTION 23-2

MANY VALVES USE BIMETAL SPRINGS WHICH OPEN OR CLOSE THE VALVE DEPENDING ON THE TEMPERATURE

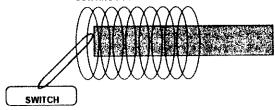


REMOTE BULBS FILLED WITH FREON CAN ALSO BE USED TO SENSE TEMPERATURES AND CONTROL EQUIPMENT - THE FREON EXPANDS ON TEMPERATURE INCREASE AND CAN "THROW" A SWITCH

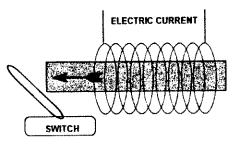


ELECTROMAGNETIC RELAYS ARE THE BASIC BUILDING BLOCK OF MANY CONTROLS

PLACE AN IRON BAR BETWEEN A CONTINUOUS COIL OF WIRE



APPLY A SMALL ELECTRICAL CURRENT TO EACH SIDE OF THE COIL, AND THE IRON BAR WILL MOVE AND THROW A SWITCH OR CONTROL A VALVE



DIFFERENTIAL CONTROLS

A differential control is used on virtually all liquid systems. Because the control is concerned with temperature <u>differences</u>, rather than absolute temperatures, it is called a <u>differential thermostat</u>.

The controller incorporates two thermistors which change electrical resistance upon temperature change (sensors). The sensors are normally attached to the collector outlet tubing and the bottom of the storage tank and wired to the controller (low voltage). When the controller senses that the collectors are warmer than the tank (9° to 20° F) an internal relay is actuated which turns the pump on. When the temperature difference between the collector and tank sensors falls to the turn off differential (normally 3° to 6° F), the pump is turned off. These two differential settings are referred to as the "delta- T on" and "delta-T off". Sometimes the two settings are shown together. For example, a control with a 20°F on differential, and a 5°F off differential would be described as a "20/5".

Most controls have a three-position switch with the functions marked "on," "off," and "auto." In the "on" position, the control ignores the sensor signals and operates the pumps constantly. In the "off" position, the sensor signals are ignored, and the pumps remain off. The "auto" position is used for normal, automatic operation.

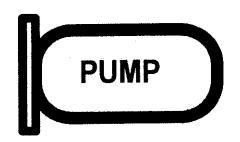
Controls and sensors are available in two types: 10K and 3K. These refer to the resistance the temperatures have at "room" temperature (77°F). A 10K sensor has 10,000 ohms resistance at this temperature, a 3K has 3,000 ohms. Consequently a 10k controller must use 10k sensors, and 3k controllers must use 3k sensors. Most controls are 10K. If you have any doubt about this, refer to the system's operation and maintenance manual. If one does not exist, remove a sensor, give it time to come to room temperature and measure its resistance with an ohmmeter.

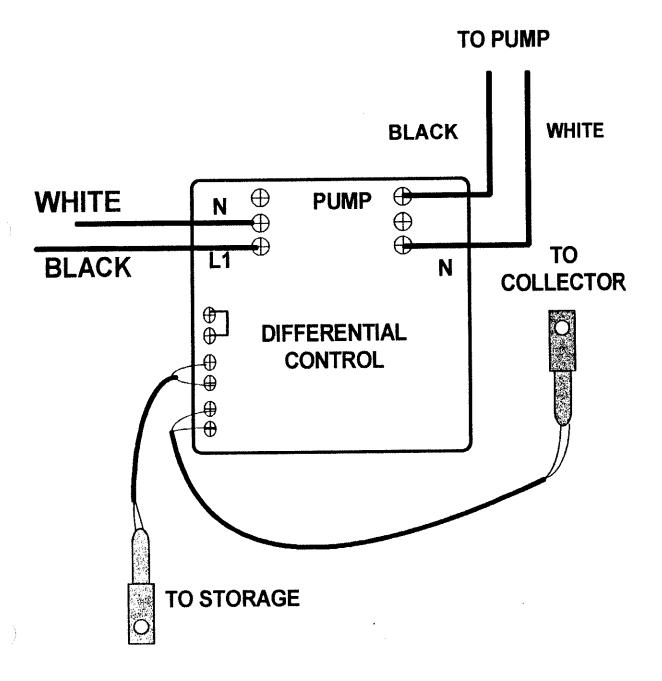
Most differential thermostats also include storage tank high limit and collector freeze protection features. When the high limit feature is activated, the collector pump turns off when the storage tank reaches a pre-set temperature (typically 160°F-180°F). When freeze protection features are selected, the control activates the solar pump for recirculation when the collectors sense near freezing conditions. Auxiliary sensors and snap switches are sometimes used in addition to the storage tank and collector thermistors.

Controls manufactured by Controlex (Natural Power), Johnson Controls, Barber Coleman, Honeywell, Robertshaw and others are <u>not</u> 10K differential thermostats. These controls use RTD sensors instead of thermistors. These controls are no longer manufactured and sensors may be hard to find.

Heliotrope General controls may use 10K or 3K sensors. The table below contains additional information on these controls. The 3K controls are no longer manufactured.

SIMPLE CONTROLS FOR SOLAR DOMESTIC HOT WATER SYSTEMS





Characteristics of Many Differential Controllers Manufacturers currently (1995) making controllers are given in bold print

Manufacturer:	Model:	Type:	On/Off: (°F)	High Limit:(°F)
Heliotrope	TempTrak II Series	3K/10K	Adj: 50-100	Adj:80-215
General*	DTT-64Series	10K	20/30 or10/3	None,160,or180
	DTT84/94Series	10K	18/5 or 9/4	160 or 180
	DTT84DD	10K	30/3	180
	DTT-74Series	10K	20/5 or 10/5	None,160,or180
Independent	GL-30/32	10K	Adj: 8-24/4	Adj: 110-230
Energy	GL-33	10K	Adj: 8-24/4	Adj: 50-104
	GL-50	10K	Adj: 15/4 to 40/20	Adj:60-160
	C-30 Series	10K	20/5 or 8/3	Adj: 105-212
	C-35Series	10K	4/1 or 8/3	Adj: 62-104
Pyramid Controls	All	10K	14/3	163
Rho Sigma	RS504 Series	10K	20/3 or 12/3*	* 160
	RS121 Series	10 K	20/3	Adj: 120-220
	RS360 Series	10K	20/3.5	Per specification

^{**} Proportional control: The pump motor is run at a speed proportional to the differential. This type of control is rarely used.

Some controls feature a digital display showing all the sensor temperatures. In many cases, these controls have added channels to allow monitoring of additional system points.

SENSORS (THERMISTORS)

Controls and Sensors

The collection system control operates by <u>comparing</u> the temperatures of the collectors and storage. When the collectors are warmer than the storage, circulator pumps are turned on. If the collector temperature falls below the storage temperature, the pumps turn off.

The control determines system temperatures with electronic sensors. These are usually resistors which change their electrical resistance with temperature. The most accurate ones used in solar systems are called resistance temperature detectors (RTD's). These are more expensive and less common than the thermal resistors called <u>thermistors</u>.

The relationship in a thermistor between electrical resistance and temperature is inverse. That is, when the sensor's temperature goes <u>down</u>, its resistance goes up. Temperature increases result in resistance <u>decreases</u>.

The construction of sensors depends on their application. Some have a mounting tab with or without a hole for a fastener. Others resemble a threaded plug. They can be very heavy or very small and light. Most are built to attach to the surface that requires sensing.

One exception is the collector sensor on pool heating systems. It is not attached to the collector. It is built and mounted on the roof or rack next to the collectors. Because it has nearly the same thermal characteristics as the collectors, it "impersonates" the collector temperature for the control to use. Thermistor sensors are available in two types: 10K and 3K. These refer to the resistance the temperatures have at "room" temperature (77°F).

A 10K sensor has 10,000 ohms resistance at this temperature, a 3K has 3,000 ohms. For example, when the environment temperature is 77°F, the 3,000 ohm sensor should read 3,000 ohms, and the 10,000 ohm sensor should read 10,000 ohms. As the temperature increases, the resistance decreases. At 92°F, a 3,000 ohm sensor reads 2,100 ohms; a 10,000 ohm sensor reads 7,000 ohms.

The general range of solar system temperatures is 70°-160°F for the tank sensor and 100°-200°F for the collector sensor depending on the time and conditions of day. If an "open" or "short" condition is indicated, check the wiring between the controller and sensor.

A common cause for an "open" condition is a broken connection between the wiring and the sensor. A "short" may be caused by a piece of metal pinching the sensor wire and conducting it to ground.

Normally, the sensors operate at only a few volts. This means sensor wiring is considered Class 2, and thus does not require conduit or armor. However, this low voltage wiring is susceptible to electrical "noise" from 120, 240 and higher voltage wiring, electric motors, radio transmitters and other sources of RF (radio frequency) noise.

The usual solution to this problem is to maintain adequate distance between the controls, sensors and wiring, and the source of noise. If this is not possible, shielded cable is used.

Install the "collector" sensor at the collector outlet header. One acceptable method is to push the "tongue" of the sensor under the grommet of the outlet pipe. Use a stainless steel hose clamp to secure the sensor. Do not overtighten the clamp!

Install the "storage tank" sensor as close to the bottom of the storage tank as possible. Sensor should be in direct contact with tank, some tanks provide a terminal post with nut for proper sensor placement.

Both collector and storage tank sensors should be well insulated from the outside ambient temperatures. Freezing cold and scorching hot ambient temperatures can and will cause sensor misreadings if the sensor is not insulated from their effects.

SENSORS - AN OHMMETER (MULTI-METER IS REQUIRED)

TEM	P. 10K	3K	TEMP.	10K	3K
27	39.8	11.9	107	5.0	1.5
32	32.6	9.8	112	4.5	1.4
37	28.3	8.5	117	4.0	1.2
42	24.7	7.4	122	3.6	1.1
47	21.5	6.5	127	3.2	1.0
52	18.9	5.7	132	2.9	0.9
57	16.5	5.0	137	2.6	0.8
62	14.5	4.4	142	2.4	0.7
67	12.8	3.8	147	2.2	0.6
72	11.3	3.4	152	2.0	0.6
77	10.0	3.0	157	1.8	0.5
82	8.8	2.7	162	1.6	
87	7.9	2.4	167	1.5	0.4
92	7.0	2.1	172	1.4	-
97	6.3	1.9	177	1.2	-
102	5.6	1.7	182	1.1	0.3

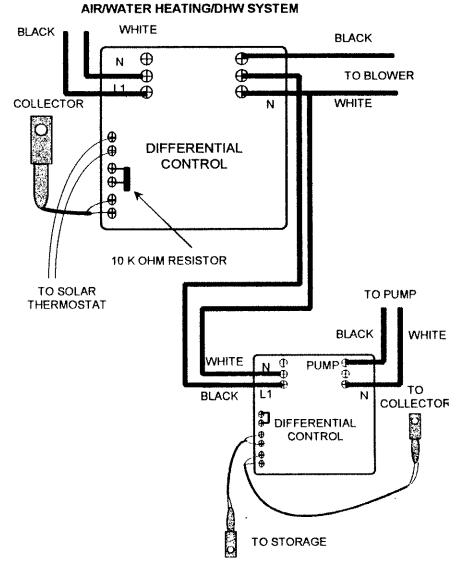
MULTI-DIFFERENTIAL CONTROLLERS

Multi-differential controllers are, as their name implies, two or more differential controllers built into the same electronics enclosure. They are not as common today as they were in years past. The reason could be that solar systems today tend to be a lot less complicated than their predecessors. Nevertheless, their benefits are worth noting.

Most muti-differential type controllers were used in combination solar/DHW/space heating type systems. One differential control would operate the solar collection pump when there was a temperature difference between collector and storage tank. Another would energize the pump collecting heat for domestic hot water when the solar storage tank became hotter than the hot water heater. In some cases, a third built-in differential control would be used for gathering heat from a water grate in a fireplace or for distributing heat to the residence.

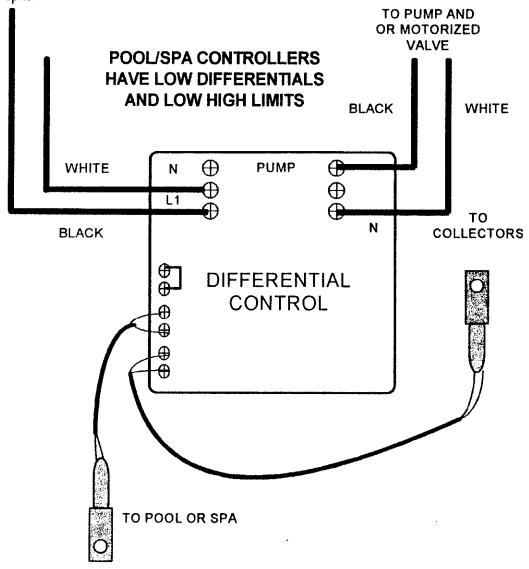
を見るというできた。 できるのでは、東京大学の経験が教養のできるというできた。

MULTIPLE DIFFERENTIALS TWO C-30 CONTROLS CONTROLLING AN



POOL / SPA CONTROLS

Simple pool controls are typically a matter of adjusting the existing timer to turn on and off the filter pump during daytime hours (9:00am-5:00PM) allowing flow to the solar pool collectors. If the system is subject to increment weather conditions, a differential controller with a diverting valve might be considered. In this case, the pool timer activates the differential controller at the same time as it activates the filter pump. Once activated the differential control measures the difference in collector and pool temperatures. Flow is diverted to the collectors when the collector sensor indicates a 5 degree higher temperature than the pool sensor. Flow bypasses collectors when the temperature differential. Additionally, the control should allow for maximum pool temperature adjustment. When this temperature is reached the control prevents flow to the collectors, even though there may still be heat available. The high temperature "cut-off" is adjustable from approximately 70 degrees F to 95 degrees F for pools and 95 degrees F to 110 degrees F for spas.



TROUBLESHOOTING

Introduction

To diagnose system problems, you must not only understand the components and how they work, but you must also know what questions to ask to find out what, when, and why the problem has occurred. The more experience you have in servicing solar systems, the more you will learn about what questions to ask the customer. This section gives some possible questions you may ask and presents important information you should be aware of when servicing solar DHW systems.

The Initial Service Call

When you first receive a service call, record the caller's name, address and phone number and be sure to get directions to the service location. Also, verify that the caller is the system owner and is authorized to have you service the system.

Determine what kind of service the caller is requesting is it a routine service call or is the system not working properly? If the system is not working, what exactly is wrong? Is there no hot water? Is the system leaking? If it is leaking, where is the leak - on the roof or at the storage tank? The more you know about the system, the better prepared you will be when you arrive at the site. For example, if the system has an expansion tank that is over two years old, you will want to take glycol with you to replace the old glycol. If the system has a drainback tank, you will want to have distilled water with you.

Avoid any misunderstanding by making your payment policy clear at the outset. For example, if the caller is renting the home, clarify whether or not you expect to be paid at the time service is rendered.

Find out the type of system, who installed it, how old it is and what previous service has been performed. Also, find out if the caller has a manual, a schematic, and a parts list for the system and what, if any, service contracts, warranties and insurance policies cover the system or its components.

Contractor Liability

Some contractors give customers advice over the telephone about how to correct a problem. If you do this, be aware of potential liability. For example, pushing the reset button on the storage tank is a very simple procedure, and you may suggest that your customers do this themselves. It saves you time and saves them the cost of a service call. But tell them first to turn off the circuit breaker. Emphasize that they should never remove the front plate on the tank until they have turned off the power.

You might rather not give any instructions over the telephone. Even if you only need to reset the heater you can make the visit worthwhile for the customer and for yourself by performing a routine service check while you are there.

Overall Check-out

You should always check the entire system while you are on a call because many times more than one problem exists. For example, you may replace a burned out pump. Later, when this new pump also burns out, you find that all along a defective valve was preventing water from getting to the pump. Keep in mind that a "system" requires proper performance of all the components working together.

While you check the system, consider ways you can improve its performance. For example, open-loop systems can include an air vent, a vacuum breaker, a pressure relief valve and a freeze valve. You will find that many open-loop systems do not have all of these components, even though each one has a definite function. You can give the customer a better working system by adding these useful components.

At the same time, do not change the system for change's sake. Some contractors do not like controllers or PV systems. So rather than make repairs, they change the whole system. If you do not want to work on one type of system, refer the job to someone else.

When you first look at a system, prepare an estimate for the customer including the cost, the results and the benefit of the repairs After you complete the repairs, test the system completely once again. Be sure that it is right. If you have to go back on a second or third call, you lose whatever money you made on your first call. And finally, point out your work so the customer knows what you have done.

Lifestyles Analysis

Some people think when they acquire a solar DHW system, they have an unlimited supply of hot water. Be sure they understand that the DHW system can provide the hottest water during the late afternoon and early evening hours. Keeping this in mind, they should use hot water during these periods to achieve the best results from the system. To minimize their back-up heating expense, they could, for example, take showers and use the dishwasher during the evening and use only small amounts of hot water in the morning. Here are some questions that you may want to ask if the complaint is "not enough hot water" or "high electric use":

- 1. How many people are using the hot water?
- 2. Have recent guests added to the water use? How many guests?
- 3. Have extra washing (clothes or dishes) demands recently been put on the system?
- 4. When is the family's major use of hot water?
- 5. Has the weather been clear, allowing the maximum solar heating? Or has it been overcast, especially around the middle of the day?

6. Are water bills higher than usual (perhaps indicating a leak in the system - perhaps a leak under the slab)?

NOTE: Remember, this is only a sample of the questions service personnel might ask.

TROUBLESHOOTING TECHNIQUES

Troubleshooting an HVAC system should involve more than looking for an obvious problem, or replacing components at random in an attempt to get the system working again. This is particularly true of solar heating systems. What is required is a systematic procedure that carefully "troubleshoots" the system until the problem is located and repaired.

Cause or Symptom

What may appear to be the <u>cause</u> of a problem may actually be a <u>symptom</u> of another problem. For example, if a sensor is secured to an ungrounded solar collector, a discharge of static electricity may travel through the sensor wire and ruin the control.

Replacing the control does not solve the problem that destroyed it. The new control is still likely to be damaged, and the system will be inoperative again. If the collector with the sensor is properly grounded, the actual problem has been solved. Now a new control can be expected to remain functional.

"Low Impact" Troubleshooting

Another peculiarity of solar systems is the difficulty of performing some troubleshooting procedures without making it a major undertaking.

As an example, it is difficult to examine the interior of the collector loop pump of a closed-loop system. The process may require completely draining the solar fluid into buckets or drums, disassembling and reassembling the pump and refilling the system loop with fluid.

On the other hand, checking the electrical current draw of the pump can confirm or deny that the pump rotor is locked. This can be done without ever opening up the collector loop. This "low impact" troubleshooting usually saves time, material and money.

Less Likely, But Easy

Most "low impact" troubleshooting is relatively quick and easy. For this reason, it may make sense to do them, even if they relate to causes you believe are unlikely. Occasionally, the cause of a problem is not one of the likely ones, and a few minutes spent performing easy operations is well-rewarded. Also, following a systematic troubleshooting procedure will uncover other problems that should be repaired for long term performance and trouble free maintenance.

SOLAR REFURBISHMENT WORKSHOP SECTION 28-4

Multiple Problems

Never assume that a system is completely without faults after correcting a problem. A few more minutes spent checking out the rest of the system may save a trip back later to "rerepair" the system.

Five Steps of Good Troubleshooting

Good troubleshooters usually follow some variation of the following steps when working:

- o Planning
- o finding the cause
- o Repairing
- o Testing
- o Keeping records

<u>Planning</u> begins with thinking about the possible causes of a problem before going to the site. This includes the tools and materials necessary to determine what is causing the problem, and estimating the time required to find and correct it. Friday afternoon at 4:00 is a bad time to start tearing down a DHW system, particularly if you may require parts which take 30 days to come in.

<u>Finding the cause</u> is the investigation phase. Start with low impact checks, proceed in an organized and logical fashion, and attempt to isolate the results of testing to the component being tested.

Repairs can be made on a "band-aid" basis, doing as little as possible to get the system running again. Another approach is to replace major portions of the system to be absolutely certain the problem is gone. The correct approach is to determine what the real cause of a problem is, and make repairs that solve that problem so it does not happen again.

Whether to repair or replace defective components depends on the cost and availability of the component. Generally, the more expensive and difficult it is to obtain something, the more appropriate the repair of the component. If the part is cheap and readily available, it generally will be replaced. If repairs can be made to the defective component, it can become the new replacement the next time this same component fails in this or other systems.

After the cause of a problem has been identified and corrected, <u>inspect and test</u> the entire system. This confirms that the new components are working, and that no other problems exist.

The defective components should be tested as well. The best time is usually before rebuilding. As an example, if a control works fine on a test bench, but not at all at the site, a problem exists at the site that will not let the new control work there either.

If the part is truly defective, look for the reason it failed. For example, did the control get wet? Will the new control also get wet and fail?

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The last part of troubleshooting is <u>record-keeping</u>. Maintenance and repair records are kept to maintain a history of each system. Troubleshooting records should be part of that written history. In addition, writing down the troubleshooting process preserves that information for the person who found the problem.

STANDARD TEST EQUIPMENT

Control Tester Method

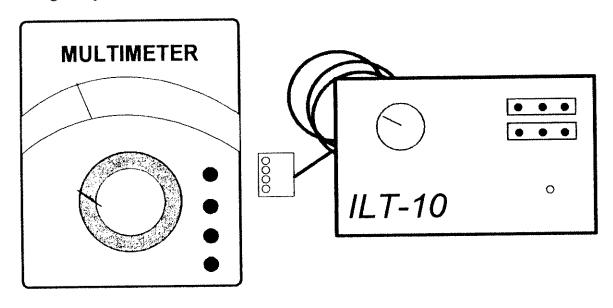
A more accurate method of testing differential thermostats is with a special tester designed for the purpose (As shown below). Normally, these units have four leads or terminals. These are connected to the collector and storage sensor terminals of the control. The tester supplies a calibrated resistance to the two sensor inputs.

Most of the available testers supply a fixed resistance to the storage terminals, and change the resistance supplied to the collector terminals. The numbers on the tester dial usually refer to the temperature difference between the storage and collector terminals.

As the tester dial is slowly turned to greater differentials, the resistance supplied to the collector sensor terminals is lowered. At the "on" differential, the control should turn on.

Next, the dial is turned slowly downward to lower differentials. This increases the resistance shown to the collector sensor terminal. At the "off" differential, the control should shut off.

Many testers also include a high limit test function. Generally, the tester shorts out the collector sensor's terminals, to ensure the control is trying to run the system. Then, the resistance supplied to the storage sensor terminals is reduced, impersonating a rising storage temperature. When the high limit is reached, the control should shut off.



EQUIPMENT SUBSTITUTIONS

PUMPS:

Many pumps can be successfully substituted for other brands. Careful consideration should be given to the generic type of pump ie. circulator, centrifugal, submersible and AC or DC electricity. If you have the same generic catagory of pump, substitution factors are head, flow rate and type of fluid. All pumps have a performance curve of flow vs. head and you should substitute with one similar. Systems using oils for the heat transfer fluid should only use pumps with viton gaskets and "O" rings. Pumps bronze or stainless housings should not be replaced with pumps with iron housings.

ROUGH EQUIVALENTS OF SOME COMMON PUMPS

TACO	GRUNDFOS	HARTELL	HEAD
		MD-3-1U	0 TO 3 FT.
006-B	15-18 SU	MD-10-1U	5 TO 10 FT.
008-F or B	15-42F or SU		10 TO 16 FT.
009-F or B.	26-96F or B		16 TO 30 FT.

TANKS:

Tanks with internal heat exchangers may be replaced by a well insulated electric water heater and an external heat exchanger. Removing the existing drain fitting on a water heater and replacing it with a "tee" will allow piping to the bottom of the tank.

CONTROLS:

Most differential controllers made today (1995) are interchangeable. Older 3K and other RTD sensor controllers should be replaced with a 10K controller and new sensors.

HEAT EXCHANGERS:

Most outdated liquid to liquid heat exchangers can be replaced with newer and more advanced models currently available. Minor piping modifications are usually required if the exchangers are of a different size.

GLOSSARY

ABSORBER -- The absorber is that part of the solar collector which receives the incident radiant energy and transforms it into heat energy.

ABSORPTIVE COATING -- Covers the absorber plate and improves its ability to absorb energy without reflecting it away.

ACTIVE SOLAR SYSTEM -- A system that traps the sun's energy and utilizes a mechanical subsystem to move that energy to its point of intended use for water heating, space heating and possibly space cooling.

AQUASTAT -- Thermostat which measures liquid temperatures.

BATCH -- Black tank that serves as both collector and storage tank. Can be enclosed, with one side glazed.

BREADBOX -- Black tank enclosed in insulated box that is glazed on one side. Tank serves as both collector and storage tank.

BRITISH THERMAL UNIT (BTU) - The amount of heat required to raise the temperature of one pound (one pint) of water, one degree fahrenheit.

CENTRIFUGAL PUMP -- A type of pump which has blades that rotate and whirls the fluid around so that it acquires sufficient momentum to discharge from the pump body. The fluid is thrown outward by centrifugal force.

CLOSED LOOP SYSTEM -- System of which no part is vented to the atmosphere or fed with fresh liquid. The system liquid is recirculated.

COIL-IN-TANK- HEAT EXCHANGER -- A coil in a water tank. Most commonly used on solar water heating systems.

COLLECTOR LOOP -- The part of the solar system that has solar collectors. The collector loop may be piped and include other components.

COLLECTOR TILT -- The angle between the horizontal plane and the solar collector plane.

COUNTER FLOW HEAT EXCHANGER -- A self- contained heat exchanger in which the two substances flow in opposite directions.

DEGREE DAY - The difference between 65° and the mean daily temperatures.

DIFFERENTIAL CONTROLLER -- Control which measures the difference between the collector and the tank temperatures.

DIFFUSE RADIATION -- Solar radiation received after its direction has been changed by reflection and scattering in the atmosphere.

DIRECT BEAM RADIATION -- Solar radiation which is not scattered by dust or water droplets. It is capable of being focused and casts shadows.

DIRECT PUMP -- Solar domestic hot water system that used existing water pressure to fill the collectors.

DOUBLE GLAZED -- Covered by two panes of glass or other transparent material.

DOUBLE WALL SEPARATION -- Heat exchangers utilizing non-potable heat transfer fluids are separated from the potable water system by use of two walls between the fluids.

DRAIN-DOWN SYSTEM -- A liquid solar collection system in which the collector fluid drains down when the collector system pump is not operating.

DRAINBACK SYSTEM -- Liquid system that only fills the collector when the temperature differential is appropriated. The water that is circulated through the collectors is stored in a reservoir.

EXPANSION TANK -- Takes up the overflow created when the heat transfer fluid expands. **FLAT PLATE COLLECTOR** -- Converts the sun's radiation into heat on a flat surface within a simple box. Does not use reflecting surfaces, lens arrangements to concentrate the sun's energy.